Alfred

MODEL 650

MANUAL # 110-6001

AAI CORPORATION
A SUBSIDIARY OF UNITED INDUSTRIAL CORPORATION
BALTIMORE, MARYLAND

INSTRUCTION MANUAL

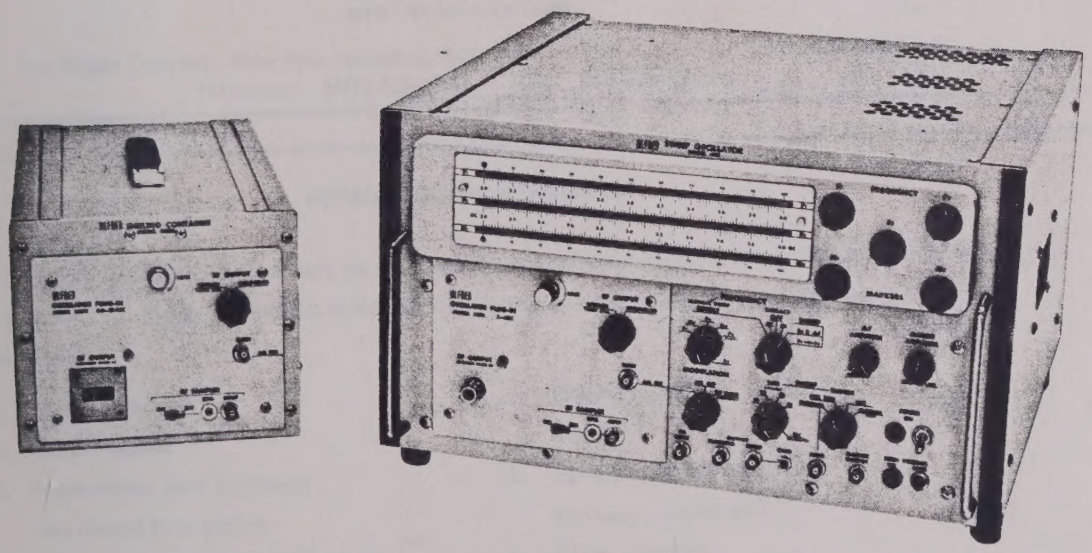
RETURN TO CALIBRATION LAB.

sweep oscillator

MODEL 650

MANUAL # 110-6001

CODE #666



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The Singer Company, Palo Alto Operation
3176 Porter Drive, Palo Alto, California 94304/ (415) 493-3231 TWX 910-373-1765

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(2) Include data on symptoms, measurements taken, test instruments used, suspected location of trouble, maintenance action taken, and any other relevant data.

MANUAL CHANGES

FOR

SWEEP OSCILLATOR MODEL 650

Make corrections to errata listed below and make applicable changes(s) listed in the table below according to instrument serial number.

SERIAL NO.	MAKE CHANGES

SERIAL NO.	MAKE CHANGES

ERRATA:

Schematic 900775 and parts list, page 6-2:
Change F1 to 2A, part no. 121-14 (When Model 650 used with Model 650-1 Solid-State Drawer)

Schematic 900905:
Change the output from A15, Pin 16, to read "PLATES of V1, V2, V3 (ON A10 ASSY)"

June 25, 1971

TABLE OF CONTENTS

Paragraph		Page
	SECTION 1 - GENERAL INFORMATION	
1.1	The Model 650 Series Sweep Oscillator	1-1
1.2	The Oscillator Plug-in Units	1-1
1.3	The Model 650 Series Power Supply Plug-in Unit	1-2
1.4	Scope of the Model 650 Series Instruction Manuals	1-5
1.5	Applications of the Model 650 Series	1-5
	SECTION 2 - INITIAL INSTRUCTIONS	
2.1	Receiving Inspection	2-1
2.2	Shipping Screws	2-1
2.3	Power Requirements	2-1
2.4	Chassis Grounding	2-1
2.5	Cooling	2-1
2.6	Checking Installed Position of Frequency Dial Plate	2-1
2.7	Incoming Inspection Test	2-2
2.8	Storage of Plug-in Units Removed from the Model 650	2-2
2.9	Returning the Instrument	2-2
	SECTION 3 - OPERATION	
3.1	Front Panel Controls	3-0
3.2	Front Panel Connectors	3-3
3.3	Rear Panel Controls and Connectors	3-3
3.4	Instrument Turn-on Procedure	3-4
3.5	Operating Procedures for Swept-Frequency Output Modes	3-4
3.6	Operating Procedures for Single-Frequency Output Mode	3-5
3.7	Selection of Sweep Time	3-6
3.8	Selection of Sweep Trigger Mode	3-6
3.9	Modulating the RF Output	3-6
3.10	Amplitude Modulation	3-8
3.11	Frequency Modulation	3-8
3.11.1	Voltage-Controlled FM Using the FM INPUT Jack	3-8
3.11.2	Remote Frequency Programming Using the REMOTE FREQ Jack	3-12
3.11.3	Remote Frequency Stabilizing and High Frequency FM Modulation (BWO Plug-in Units Only)	3-14
3.12	RF Output Leveling and Power Level Adjustment	3-15
3.12.1	General Data	3-15
3.12.2	Leveling with Internal Sampling (650K and AK Series Plug-in Units Only)	3-16
3.12.3	Leveling with External Sampling (All Plug-in Units	3-17
3.12.4	External Power Level Control and Programming	3-18
3.12.5	Adjustment of Power Level in Unleveled Operation (650A and AK Plug-in Series Only	3-19
3.12.6	Adjustment of Power Level in Unleveled Operation (650 and 650K Plug-in Series Above 12.4 Gc Only)	3-19
3.13	Use of Markers	3-19
3.14	RF Output Blanking During Sweep Retrace	3-19
3.15	Auxiliary Output Signals	3-19
3.16	Remote Control and Programming	3-20
3.17	Applications Information	3-20
3.17.1	General	3-20
3.17.2	Readout Display Techniques	3-20
3.17.3	Reflectometer Techniques for VSWR Measurement with Flat, Pre-Calibrated Display	3-21
3.17.4	Reflectometer Techniques for VSWR Measurement without Flat Display	3-22
3.17.5	Basic Technique for Measurement of Gain and Loss	3-23
3.17.6	Technique for Transmission Measurements with Flat, Pre-Calibrated Display	3-24
3.17.7	Technique for VSWR Measurements with Direct-Reading Meters	3-27
3.17.8	Technique for Power Measurement with Direct-Reading Meters	3-27
	SECTION 4 - CIRCUIT DESCRIPTION	
4.1	Block Diagram Description	4-1
4.2	Primary Power Distribution	4-5
4.3	+15 and -15 Volt Power Supplies	4-5
4.4	+100 and -50 Volt Power Supplies	4-5
4.5	Cathode Supply	4-6
4.6	Heater Supply	4-8
4.7	Heater Overvoltage Protection Circuit	4-8
4.8	Helix Overcurrent Protection Circuit	4-8
4.9	Anode Supply	4-9
4.10	-100 Volt Supply	4-9
4.11	Sweep Generator	4-10
4.12	Sweep Output Circuit	4-11
4.13	Marker Generator Circuit	4-12
4.14	Modulator	4-13
4.15	Transfer Oscillator	4-14
4.16	Frequency Control Switching	4-14
4.17	Modulation and Sweep Control Switching	4-14
	SECTION 5 - MAINTENANCE	
5.1	Periodic Maintenance	5-1
5.2	Voltage Measurements at Chassis Test Points	5-1
5.3	Internal Adjustments	5-1
5.4	Trouble Shooting	5-8
5.5	Alignment of Plug-in Unit	5-18
5.6	Replacement of Frequency and Marker Potentiometers	5-18
5.7	Replacing the Microwave Tube	5-20
5.8	Replacement of Other Components and Controls	5-22
	SECTION 6 - PARTS LIST	
	List of Assemblies	6-1
	Main Chassis Parts	6-2
	A1 PC Board Assembly Parts	6-5
	A2 PC Board Assembly Parts	6-5
	A3 PC Board Assembly Parts	6-6
	A4 PC Board Assembly Parts	6-7
	A5 PC Board Assembly Parts	6-8
	A6 PC Board Assembly Parts	6-9
	A7 PC Board Assembly Parts	6-9
	A9, A10, A15, A26 PC Board Assembly Parts	6-10
	Vendor Codes	6-11
	SECTION 7 - SCHEMATIC DIAGRAMS	

LIST OF ILLUSTRATIONS

Title	Page
SECTION 1 - GENERAL INFORMATION	
Model 650 Installation Drawing	1-3
SECTION 2 - INITIAL INSTRUCTIONS	
op View of Typical Oscillator Plug-in Unit Showing Stored Position of Frequency Dial Plate	2-1
SECTION 3 - OPERATION	
ront Panel	3-0
ear Panel	3-2
ear Panel Connections for External Power Level Programming or Amplitude Modulation with Leveled Output	3-7
Maximum Allowable Modulating Voltage vs Modulating Signal Frequency for Large-Signal FM Modulation at FM INPUT Jack	3-9
Modulation Response vs Modulating Signal Frequency for Small-Signal FM Modulation at FM INPUT Jack	3-9
Maximum Frequency-Shift Rate for Externally-Driven Sweep or External Frequency Programming	3-13
ear Panel Connections for Remote Frequency Programming	3-13
ear Panel Connections for Remote Frequency Stabilization or High-Frequency FM Modulation	3-15
ypical Leveler Performance	3-15
ypical Connections for External Leveling	3-17
eflection Coefficient (VSWR) Measurements Using Calibrated Oscilloscope or Recorder	3-21
General-Purpose Test Set-up for Swept or Single-Frequency Measurements	3-24
ransmission Loss Measurements Using Calibrated Oscilloscope or Recorder	3-26
ransmission Gain Measurements Using Calibrated Oscilloscope or Recorder	3-26
SECTION 4 - CIRCUIT DESCRIPTION	
lock Diagram of Model 650 Series Sheet 1: Power Supply Circuits	4-0
Sheet 2: RF Output, Frequency Control, and Modulation Circuits	4-2

Figure	Title	Page
	SECTION 4 - CIRCUIT DESCRIPTION (continued)	
4-2	Primary Power Distribution	4-15
4-3	-15 Volt Supply	4-17
4-4	+15 Volt Supply	4-17
4-5	+100 Volt Supply	4-19
4-6	-50 Volt Supply	4-19
4-7	Cathode Supply	4-21
4-8	Sweep Retrace Discharge Circuit	4-23
4-9	Heater Supply	4-23
4-10	Protection Circuits	4-23
4-11	Anode Supply	4-25
4-12	-100 Volt Supply	4-25
4-13	Sweep Generator	4-27
4-14	Sweep Output Circuit	4-29
4-15	Marker Generator	4-29
4-16	Modulator and Transfer Oscillator Circuits	4-31
4-17	Schematic and Wiring Diagram of FREQUENCY Mode Selector Switch S14 and SINGLE Frequency Selector Switch S15	4-33
4-18	Schematic and Wiring Diagram of MODULATION SWEEP TIME, and SWEEP TRIGGER Selector Switches	4-35
	SECTION 5 - MAINTENANCE	
5-1	Top View of Chassis	5-2
5-2	Right-Side View of Chassis	5-3
5-3	Left-Side View of Chassis with Typical Plug-in Installed	5-4
5-4	Bottom View of Chassis	5-5
5-5	Detail View of High Voltage Rectifier Circuit Board	5-22
5-6	Detail View of Auxiliary Signal	5-22
5-7	Detail View of High Voltage Tube Subchassis	5-23
5-8	Graph of Anode Feedback Resistor Values vs Required Anode Supply Output Voltage for Plug-in Units	5-23
	SECTION 7 - SCHEMATIC DIAGRAMS	
	Schematic Diagram Index	7-0

LIST OF TABLES

Title	Page
SECTION 1 - GENERAL INFORMATION	
pecifications of Model 650 Series Sweep Oscillators	1-2
pecifications of 650 Series Oscillator Plug-in Units	1-4
pecifications of Model 650-P1 Plug-in Power Supply	1-5
SECTION 3 - OPERATING INSTRUCTIONS	
Description of Front Panel Controls and Indicators	3-0
Description of Front Panel Connectors	3-3
Description of Rear Panel Controls and Connectors	3-3
SECTION 4 - CIRCUIT DESCRIPTION	
rinted Circuit Cards in the Model 650 Series	4-4

Table	Title	Page
	SECTION 5 - MAINTENANCE	
5-1	Test Point Measurements	5-6
5-2	Trouble-Shooting Chart for the Model 650	5-10
5-3	Trouble Shooting the Low Voltage Supplies	5-13
5-4	Trouble Shooting the Sweep Generator Circuit	5-14
5-5	Trouble Shooting the Helix Overcurrent Protection Circuit and Collector Current Monitoring Circuit	5-15
5-6	Trouble Shooting the Heater Supply and Heater Overvoltage Protection Circuits	5-16
5-7	Trouble Shooting the -100 V Supply	5-16
5-8	Trouble Shooting the Anode Supply	5-16
5-9	Trouble Shooting the Cathode Supply	5-16
5-10	Trouble Shooting the Modulator and Transfer Oscillator	5-17
5-11	Trouble Shooting the Marker Generator	5-18

SECTION 1

GENERAL INFORMATION

1.1 THE MODEL 650 SERIES SWEEP OSCILLATOR.

The Model 650 instrument operates as a sweep oscillator when combined with any one of a family of Oscillator Plug-in units, Models 651 through 659. The swept frequency output is a linear function of time, and both sweep width and sweep rate can be independently adjusted over a wide range. In addition to its swept rf output, the instrument can supply stable single-frequency signals, tunable anywhere in its frequency range, with stability rivaling that of mechanically-tuned signal generators. A large selection of Oscillator Plug-in units is provided, covering the frequency range from 250 Mc to 40 Gc. The plug-in units are completely interchangeable, so that any plug-in can be used with any Model 650 without readjusting or calibrating either the plug-in or the Model 650. This versatile operation is obtained because the 650 Series is designed so that all different voltages, biasing connections, etc., required by each different microwave tube are obtained from standard circuits in the main chassis through different dropping and feedback networks contained in the plug-in units. Thus, all Model 650 units are calibrated against a "standard" plug-in and all plug-in units are factory-calibrated to operate with the "standard" outputs from the Model 650.

All plug-in units contain a linearly calibrated frequency dial plate which is stored in the top of the plug-in chassis, and is attached to the dial panel of the Model 650 when that particular plug-in is used. A Model 9000 Storage Container is available for the plug-in units to provide convenient, antimagnetic protective storage when the unit is removed from the Model 650. For versatility, the Model 650 Series offers three sweep modes, three markers, five adjustable frequencies, internal and external modulation and leveling capabilities, display outputs, and other features.

The instrument provides two electronically controlled automatic sweeps (broadband and narrow-band symmetrical sweep), and manual sweep modes. The broadband sweep covers all or any portion of the full frequency range from 100% to 2%. During narrow-band symmetrical sweep operation, the frequency can be swept up to ± 5% of the full frequency range, about any desired center point. These sweeps can be triggered automatically in a free-running mode or from the line. An external trigger source or manual triggering also can be used. Sweep speed can be adjusted over a range of .01 to 100 seconds for the full frequency band. During manual sweep, the frequency can be manually swept over the full range of the instrument or between preset start and stop frequencies.

Frequency markers are available in all the sweep modes. Three rf modulated frequency markers are provided during leveled operation. They appear as rf absorption at the frequencies selected by the marker controls. If markers are needed when the rf power is unleveled, video pulse markers are available at the MARKER OUTPUT connector for combination with the rf detector output display.

Several voltages are available for oscilloscope and recorder control. For X-axis deflection of oscilloscopes and recorders a +15 V sweep voltage coincident with the rf sweep is available. A +50 V blanking signal is available during retrace. Also during retrace, at sweep speeds greater than 1 second, a relay with isolated S. P. D. T. contacts may be used to operate a recorder pen lift. The rf output may be either left on or turned off automatically during retrace.

The rf output may be amplitude modulated by either an external signal or an internally generated square wave. The square wave frequency is continuously adjustable from 800 to 1200 cps. Provision is made to permit externally controlled frequency modulation of the rf output. The rf output may be leveled across all or any portion of the band. The method of leveling and the provision of an internal leveling sampler depends upon the plug-in used. See Section 1.2 below.

The Model 650 instrument constitutes the main chassis which contains common power supply, frequency control, and modulation circuits, and an opening for one interchangeable plug-in unit. Specifications of the Model 650 Series Sweep Oscillators are given in Table 1-1. The microwave source used in the Model 650 Series is contained in the plug-in units, and is either a backward wave oscillator (BWO) or a voltage-tuned magnetron (VTM). Both tube types are encapsulated for protection and are easily replaced. Protective circuits reduce the likelihood of damage to the tubes. An internal time meter in each plug-in indicates hours of microwave tube operation.

1.2 THE OSCILLATOR PLUG-IN UNITS.

The Oscillator Plug-in units contain the rf components and the power supply coupling stages that connect the high voltage supplies and modulating circuits in the Model 650 to each tube.

The oscillator Plug-in units are divided into six groups: The Model 650 Series, the Model 650K Series, the Model 650A Series, the Model 650AK Series, the Model 650C Series*, and the Model 650CK Series*. These series differ in the type of rf leveling arrangements provided, as described below. Specifications and tube data for all Oscillator Plug-in units are given in Table 1-2.

1.2.1 THE MODEL 650 SERIES PLUG-IN UNITS. The Model 650 Series plug-in units provide an unleveled rf signal and cover the frequency range from 500 Mc to 40 Gc. They contain a leveler amplifier but do not contain an rf sampler component. Thus, the rf output can be leveled with an external sampler connected to the rf sampler input jack to drive the leveler amplifier. In the Model 650 Series, the leveling signal is coupled to the grid (BWO) or injector (VTM) of the microwave tube and the units are therefore designated as "grid leveled" type units. All modes of operation may be used in both the leveled and unleveled conditions. In the units operating below 12.4 Gc, the rf power output can be varied during leveled operation only. Above 12.4 Gc, a flap attenuator allows the power to be varied during unleveled operation also.

1.2.2 THE MODEL 650K SERIES PLUG-IN UNITS. The Model 650K Series plug-in units provide either a leveled or unleveled rf signal and cover the frequency range from 500 Mc to 18 Gc. They contain a leveler-amplifier and an internal rf sampling component. The leveler signal is coupled to the grid (BWO) or injector (VTM) of the microwave tube so that these units are also designated as "grid leveled" type units. The Model 650K Series also allows use of an external sampling component to level the rf signal at the load. A front panel switch selects either internal or external sampling. All modes of operation

*The Model 650C and 650CK are later production series containing an improved PIN diode leveler and which supersede the earlier 650A and 650AK Series in frequency bands above 1 Gc.

Table 1-1 Specifications of Model 650 Series Sweep Oscillators

Frequency Range: 0.01 to 40 Gc with appropriate Oscillator Plug-in unit(s) (see Table 1-2).

Leveling: Closed loop feedback control system provides leveling; mode of operation depends upon oscillator plug-in unit used:

Every Model 650 and 650K Series plug-in includes a leveler-amplifier connected for grid leveling. The Model 650 Series requires an external rf sampler for leveling rf power. The Model 650K Series includes the rf sampler mounted internally. A selector switch and BNC connector are provided on the front panel for external leveling.

Every Model 650A and 650AK unit and every Model 650C and 650CK unit includes a leveler-amplifier connected to an internal PIN diode leveler. The Model 650A and Model 650C Series requires an external rf sampler for leveling the output power. The Model 650AK and Model 650CK Series includes the rf sampler mounted internally. A selector switch and BNC connector are provided on the front panel for external leveling.

Power Level Control: 650K Series (all units) and 650 Series (below 10.0 Gc) are grid controlled and have power control available during leveled operation only. 650 Series (above 10.0 Gc) have power control during both leveled and unleveled operation. 650A, 650C, 650AK, and 650CK Series are PIN diode controlled and provide power control during leveled and unleveled operation.

Sweep Modes: Broadband sweep ($F_1 \rightarrow F_2$) continuously adjustable anywhere in the band. Symmetrical sweep ($F_0 \pm \Delta F$) adjustable from 0 to 10% of range anywhere in band, around an adjustable center frequency F_0. Manual sweep varies frequency between the limits set with controls F_1 and F_2.

Sweep Time: Continuously variable, 10 milliseconds to 100 seconds per sweep.

Sweep Recurrence Triggering Control: External, free running, line, or manual (single sweep). Panel button for manual triggering.

Single-Frequency Output Mode: Five stable single frequencies may be pre-set with controls F_0, F_1, F_2, M_1 and M_2, and selected interchangeably. This mode of operation permits use of the 650 Series Sweep Oscillators to replace mechanically tuned signal generators. The "single frequency" signals are stable within ±.004% (±.001% on some ranges), and external frequency or phase-locking discriminators can be used to obtain ultra-stable output.

Remote Frequency and Power Control: Available through use of 1000-ohm voltage dividers or porentiometers.

Sweep Output: 0 to 15 V sawtooth proportional to frequency during $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweeps. During F_0, M_1, and M_2 single-frequency operation, 0 to 15 V output is proportional to frequency. During manual sweep, output varies linearly 0 to 15 V as frequency is varied from F_1 to F_2.

Blanking Output and Pen Lift: +50 V signal available during sweep retrace. Pen lift relay S. P. D. T. contacts operated during sweep retrace on two slowest sweep ranges.

Rf Retrace On-Off: Rf signal on or completely off during retrace.

Frequency Markers: M_1, M_2 and F_0. Available either as pips in rf signal or as video pulses.

Frequency Stability: Better than 0.01% per degree C.

Internal Amplitude Modulation: Square wave, adjustable from 800 to 1200 cps.

External Amplitude Modulation: For leveled operation, or for slow-speed on-off keying in unleveled operation, +10 V will turn on rf signal to pre-set power level. For pulse modulation in unleveled operation, a greater voltage, depending on the plug-in, is required for full on-off. This is less than 50 V for 1 to 8 Gc and less than 100 V for 7 to 40 Gc.

External Frequency Modulation: 15 V peak-to-peak deviates frequency over full range. Response, approximately dc to 10 kc. High-frequency fm requiring greater drive voltage is available through helix modulation in BWO plug-in units. A maximum of 100 V peak-to-peak is required.

Spurious Signals: Non-harmonic 40 db, harmonic 20 db below rated output.

Power Input: 105 to 125 V or 210 to 250 V, 50/400 cps. Approximately 150 voltamperes.

Mounting Data: Removable cabinet sides permit rack-mounting.

Dimensional Data: Refer to the installation outline drawing, Figure 1-1.

can be used in both the leveled and unleveled conditions. The power can be varied during leveled operation only.

1.2.3 THE MODEL 650AK and 650CK SERIES PLUG IN UNITS

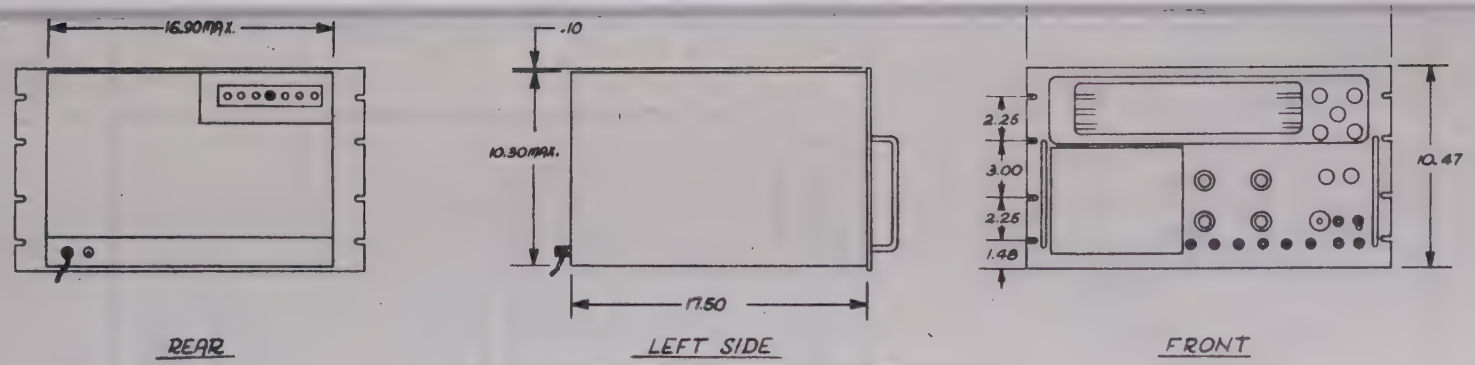
The Model 650A and 650C Series plug-in units provide an unleveled rf signal and cover the frequency range from 250 Mc to 12.4 Gc. They contain a leveler amplifier but do not contain an rf sampler component. Thus, the rf output can be leveled with an external sampler connected to the rf sampler input jack to drive the leveler amplifier. In the Model 650A and 650C series, the leveling signal is coupled to a PIN diode attenuator which provides the leveling. Hence, these units are designated as "PIN diode leveled"or "solid state leveled" type units. All modes of operation can be used in both the leveled and unleveled conditions and the power can be varied in both conditions.

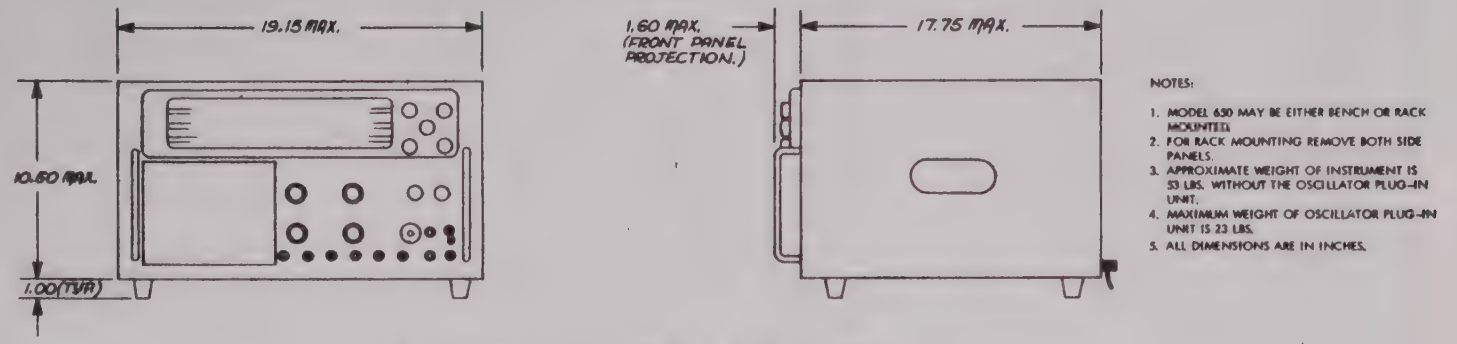
1.2.4 THE MODEL650AK and 650CK SERIES PLUG-IN UNITS.

The Model 650AK and 650CK Series plug-in units provide either a leveled or unleveled rf signal and cover the frequency range from 250 Mc. to 12.4 Gc. They contain a leveler-amplifier and an internal rf sampling component that is coupled to a PIN diode attenuator which provides the leveling. Hence, these units are designated as "PIN diode leveled" or "solid state leveled" type units. The Model 650AK and 650CK Series also allows use of an external sampling component to level the rf signal at the load. A front panel switch selects either internal or external sampling. All modes of operation can be used in both the leveled and unleveled conditions, and the power can be varied in both conditions.

1.3 THE MODEL 650 SERIES POWER SUPPLY PLUG-IN UNIT.

Also available in the Model 650 Series is a Power Supply Plug-in unit, the Model 650-P1. When combined with a Model 650, it provides an instrument which operates as a sweeping cathode power supply which can be swept over all or any part of the range -150 V to -2500 V with respect to ground, and also provides a complete set of biasing signals for BWO's, VTM's or other microwave tubes having similar power requirements. Specifications for this plug-in unit are given in Table 1-3.




19.15 MAX.
10.50 MAX.
1.00 (TYP.)
1.60 MAX. (FRONT PANEL PROJECTION.)
17.75 MAX.
NOTES:
1. MODEL 650 MAY BE EITHER BENCH OR RACK MOUNTED.
2. FOR RACK MOUNTING REMOVE BOTH SIDE PANELS.
3. APPROXIMATE WEIGHT OF INSTRUMENT IS 53 LBS. WITHOUT THE OSCILLATOR PLUG-IN UNIT.
4. MAXIMUM WEIGHT OF OSCILLATOR PLUG-IN UNIT IS 23 LBS.
5. ALL DIMENSIONS ARE IN INCHES.
INSTRUMENT WITH SIDE PANELS INSTALLED.

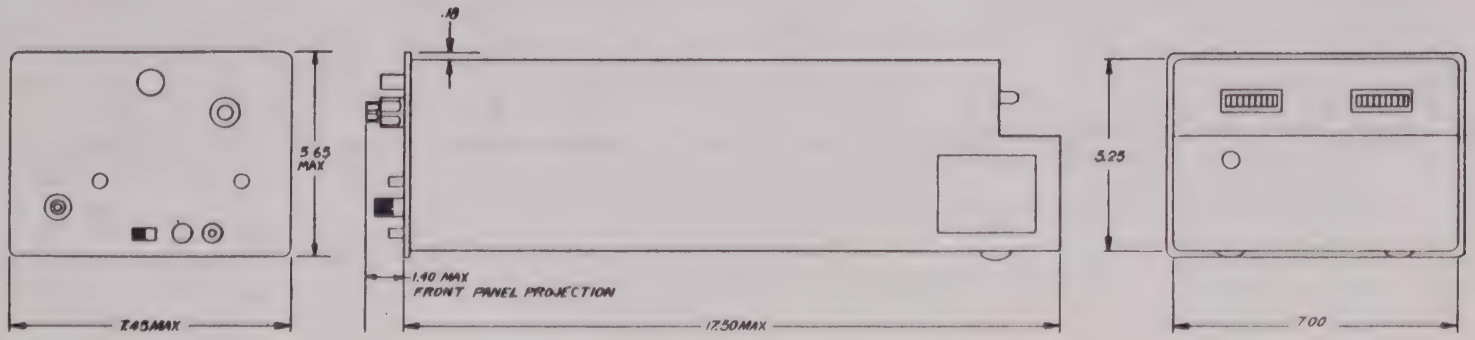


FIGURE 1-1. MODEL 650 INSTALLATION DRAWING

FREQUENCY GHz	Model*	Power Output mw	Power Variation Leveled-db **	Price U.S. $	Model*	Power Output mw	Power Variation Leveled-db **	Price U.S. $	Plug-in Unit Instruction Manual†† PIN-Leveled	Plug-in Unit Instruction Manual†† Grid Leveled	Tube Type and Vendor ***	Corresponding ALFRED Tube Part No.
10 MHz to 2 GHz					650-10C 650-10CK	3 dbm < 1 GHz 17 dbm 1-2 GHz	-- ±0.7	Special	650-10		Solid State VTO-ALFRED	----
0.25 to 0.5					651A-S2 651AK-S2	25 20	-- ±0.3	2000 2450	-7		VTM-EIM	112-001
0.5 to 1.0					651A-S3 651AK-S3	50 40	-- ±0.3	2000 2450	-7		VTM-EIM	112-003
1 to 2	651 651K	80 70	-- ±0.3	1900 2200	651C 651CK	60 40	-- ±0.3	2325 2625	-6	-1	BWO STW	112-029
1.4 to 2.5	651-S1 651K-S1	80 70	-- ±0.3	2050 2400	651C-S1 651CK-S1	50	-- ±0.3	2500 2850	-6	-1	BWO STW	112-034
1.7 to 4.2	652-S5 652K-S5	35 30	-- ±0.5	2050 2350	652C-S5 652CK-S5	15	-- ±0.5	2450 2750	-6	-1	BWO STW	112-033
2 to 4	652 652K	70 60	-- ±0.3	1700 2000	652C 652CK	40 30	-- ±0.3	2150 2450	-6	-1 / -1 / -3,5	BWO STW / W/J / VA	112-031 / 112-095 / 112-015
3.5 to 6.7	653-S1 653K-S1	40 30	-- ±0.4	2000 2400	653C-S1 653CK-S1	20 15	-- ±0.4	2250 2650	-6	-1 / -3,5	BWO STW / VA	112-035 / 112-116
3.7 to 8.3	653-S2 653K-S2	10	-- ±0.5	1950 2300	653C-S2 653CK-S2	5	-- ±0.5	2300 2650	-6	-1 / -3,5	BWO STW / VA	112-028 / 112-117
4 to 8	653 653K	40 25	-- ±0.5	1575 1925	653C 653CK	15	-- ±0.5	2000 2350	-6	-1 / -1 / -3,5	BWO STW / W/J / VA	112-027 / 112-105 / 112-006
7 to 11	654 654K	35 25	-- ±0.5	1625 2000	654C 654CK	10	-- ±0.5	2025 2400	-6	-1 / -3,5	BWO W/J / VA	112-039 / 112-012
7 to 12.4	654-S1 654K-S1	35 25	-- ±0.75	1825 2225	654C-S1 654CK-S1	10	-- ±0.75	2250 2650	-6	-1 / -3,5	BWO W/J / VA	112-039 / 112-012
8 to 12.4	655 655K	75 50	-- ±0.5†	1575 1950	655C 655CK	20	-- ±0.5†	2025 2400	-6	-1 / -3,5	BWO W/J / VA	112-038 / 112-013
10 to 15.5	656	35	--	2500						-3,5	BWO VA	112-014
12.4 to 18	657 657K	40 25	-- ±0.8	1750 2300						-1 / -3,5	BWO W/J / VA	112-109 / 112-009
18 to 26.5	658	20	--	2600						-1 / -3,5	BWO W/J / VA	112-110 / 112-010
26.5 to 40	659	>5	--	4300						-1 / -3,5	BWO W/J / VA	112-111 / 112-011

†8.2 to 12.4 GHz; ±0.7 for 8.0 to 12.4. ††Earlier 650A or 650AK Series with Stewart tubes use the -2 manual. Earlier 650A or 650AK Series with Varian tubes use the -4 manual.

*K suffix indicates rf leveling sampler mounted internally. Basic model and C- or A-suffix model require an external rf sampler for leveling. Model 650-10C is a special.

**Level variation limits shown for units with internal leveler-sampler can be achieved with at-the-load leveling in all units, by use of a suitable external sampler. Specifications and prices subject to change without notice.

***Tube Type and Vendor Code

BWO = Backward Wave Oscillator STW = Stewart VA = Varian EIM = Eimac W/J = Watkins-Johnson

VTM = Voltage tuned magnetron

VTO = Voltage tuned oscillator

Table 1-2. Specifications of 650 Series Oscillator Plug-in Units. Revised 2/9/70

Table 1-3. Specifications of Model 650-P1
Plug-in Power Supply

CATHODE SUPPLY

Voltage: -150 to -2500 V. Cathode supply can be operated at any fixed voltage or can be swept over any range between -150 and -2500 V. Voltage varies exponentially with time. Dial calibration is logarithmic. (Other voltage ranges and voltage curves are available on special order.)*

Current: 25 ma maximum.

Ripple: 15 mv peak to peak or .002% peak to peak whichever is greater (3 cycles to 250 kc).

Regulation

Load: 0.75 V from no load to full load. (Recovery time is less than 30 microseconds.)

Line: ± 0.1% for 10 V line variation.

Flyback Recovery Time: 4 milliseconds from -2500 to -150 V with no load (less with load).

Dial Calibration: ± 1%

ANODE SUPPLY

Voltage: Adjustable to any value between 35 and 280 V.

Current: 10 ma at 35 V, 1 ma at 280 V (varies linearly with voltage).

Ripple: Less than 2 mv peak to peak.

Regulation: ± 100 mv or ± 0.1%, whichever is greater, for ± 10 V line variation.

Calibration Accuracy: ± 1%

GRID SUPPLY

Voltage: Unmodulated; 0 to 100 V, adjustable. Modulated; 0 to 80 V adjustable.

Current: 1 ma maximum.

Ripple: Less than 15 mv peak to peak.

Regulation: Less than ± 100 mv for ± 10 V line variation.

Calibration Accuracy: ± 1 %

Modulation: Rise and fall time: 20 microseconds. Source impedance: less than 3 K. Internal square wave modulation is provided from the basic Model 650.

The negative side of the anode supply is permanently connected to the positive side of the grid supply. Thus, by connecting the cathode to one of the anode or grid supply terminals, it is possible to obtain various anode and grid supply voltages.

HELIX

Overcurrent Protection: Connected to ground through 35 ohms to provide overcurrent protection.

Overcurrent Trip: Adjustable from 3 ma to 25 ma.

COLLECTOR SUPPLY

Voltage: +100 V dc, ± 3%, relative to helix (ground).

Current: 25 ma maximum.

Ripple: Less than 1 mv peak to peak.

HEATER SUPPLY

Voltage: 6.3 V dc ± 1%

Current: 2 amperes maximum.

Ripple: Less than 25 mv peak to peak.

Regulation: Less than ± 0.2 V with load variation of 0 to 2 amperes.

* On special order any voltage range between the limits of -150 V and -2500 V can be provided. Also, special curves of voltage versus sweep time can be provided between linear and exponential (d^2v/dt^2 must be positive or zero). Dial may be calibrated in voltage or frequency.

1.4 SCOPE OF THE MODEL 650 SERIES INSTRUCTION MANUALS.

This Instruction Manual provides detailed descriptive data, operating instructions, circuit theory, and servicing information for the Model 650 instrument, and general information covering interface with the plug-in units. This manual can be used alone for operating the Model 650 instrument with any oscillator plug-in unit. More detailed theory and servicing information for each plug-in unit is given in the separate Oscillator Plug-in Instruction Manuals. There are eight different manuals for plug-in units identified by dash numbers in Table 1-2, which cover "families" of plug-in units having similar microwave tubes and leveling provisions. Each of these manuals includes both data applicable to the entire "family" and specific information for each model plug-in.

A separate manual is provided for the Power Supply Plug-in unit. It contains operating instructions for the Model 650 when used with that plug-in unit.

1.5 APPLICATIONS OF THE MODEL 650 SERIES.

By offering both swept-frequency and stable fixed-frequency output, with many modulation and control options, the Model 650 Series instruments can fulfill practically any requirement for microwave signal generation. They can be used to drive advanced swept-frequency test setups or for precision single-frequency tests. They can be amplitude-modulated, pulse-modulated, frequency-modulated, and remote-programmed to meet special systems requirements. Detailed operating instructions for use of the instrument in its various operating modes are given in Section 3. Contact the factory or your ALFRED representative if you need information regarding special applications.

SECTION 2

INITIAL INSTRUCTIONS

2.1 RECEIVING INSPECTION. Upon receiving your Model 650 with an installed Oscillator Plug-in unit, carefully unpack the instrument and check for shipment damage. If some damage is evident, file a claim against the carrier. Refer to the Shipment Damage Claim form in the back of this manual.

CAUTION

THE PLUG-IN UNIT CONTAINS A MICROWAVE TUBE WHICH IS EXTREMELY SENSITIVE TO FERROUS MATERIAL. USE ONLY NON-MAGNETIC SCREWDRIVERS AND OTHER TOOLS WHEN WORKING AROUND THE PLUG-IN UNIT, AND REMOVE YOUR WRIST WATCH TO AVOID MAGNETIC DAMAGE TO IT. WHEN REMOVED FROM THE MODEL 650, THE PLUG-IN UNIT SHOULD BE KEPT AT LEAST SIX INCHES FROM MAGNETIC MATERIALS.

2.2 SHIPPING SCREWS. The installed plug-in unit is secured to the Model 650 for shipping with four screws, two located underneath the unit and two at the rear (Figure 3-2). They are used to prevent plug-in damage. Prior to regular use of the unit, these screws must be removed. They are easily identifiable by arrows marked on the rear and bottom of the cabinet. An aluminum shipping plate is installed over the dial plate area of the panel to protect the dial indicator mechanism. Remove this plate by removing its two knurled attaching screws, to allow installation of the frequency dial plate contained in the plug-in unit

2.3 POWER REQUIREMENTS. The unit is normally connected at the factory for operation at 105 to 125 V ac (115 V ac nominal) and 50 to 400 cps. However, provisions are provided for easy conversion to operation at 210 to 250 V ac (230 V-ac nominal). With the top cover removed, locate the power switch labeled 115 VAC (Figure 5-1). Remove the plate and move the switch forward to its alternate position. Turn the plate over and replace it with 230 VAC showing. To reconvert for 115 V ac operation, reverse the above procedure.

2.4 CHASSIS GROUNDING. The instrument is supplied with a three-conductor power cord and a three-prong plug, which grounds the instrument when plugged into an appropriate receptacle. If a three-prong to two-prong adapter is used, make sure the unit is properly connected to ground by grounding the adapter pigtail lead.

WARNING

FAILURE TO PROPERLY GROUND THE INSTRUMENT CAN DEGRADE ITS PERFORMANCE AND STABILITY, AND COULD ALLOW AN ABOVE-GROUND POTENTIAL TO BUILD UP ON THE CHASSIS, WHICH COULD BE DANGEROUS TO OPERATING PERSONNEL.

2.5 COOLING. Adequate space must be provided at the top, rear and bottom of the unit for cooling purposes. Although most of the Model 650 Series oscillator plug-in units do not require forced air cooling, due to use of all-solid-state components in most circuits, proper ventilation for convection cooling is required, with one inch at the top and one-half inch at the bottom.

2.6 CHECKING INSTALLED POSITION OF FREQUENCY DIAL PLATE. (See Figures 2-1 and 3-1.) At the low-frequency end of the frequency dial plate, at both top and bottom, there are calibration markers consisting of a transparent circle partially bisected by the black line which denotes the low-end frequency. The proper calibrated position of the dial plate is with these circles positioned so they are centered on the white line behind the plate (on the dial plate area of the panel). This aligns the low-end frequency marks with these white calibration lines. Check whether the dial plate has shifted from the calibration position during shipping. If necessary, loosen the two attaching thumb screws and move the frequency dial plate sideways as required to achieve this calibrated alignment. Then retighten the two thumb screws. The instrument is now calibrated to the frequency range of the oscillator plug-in from which the dial plate was removed.

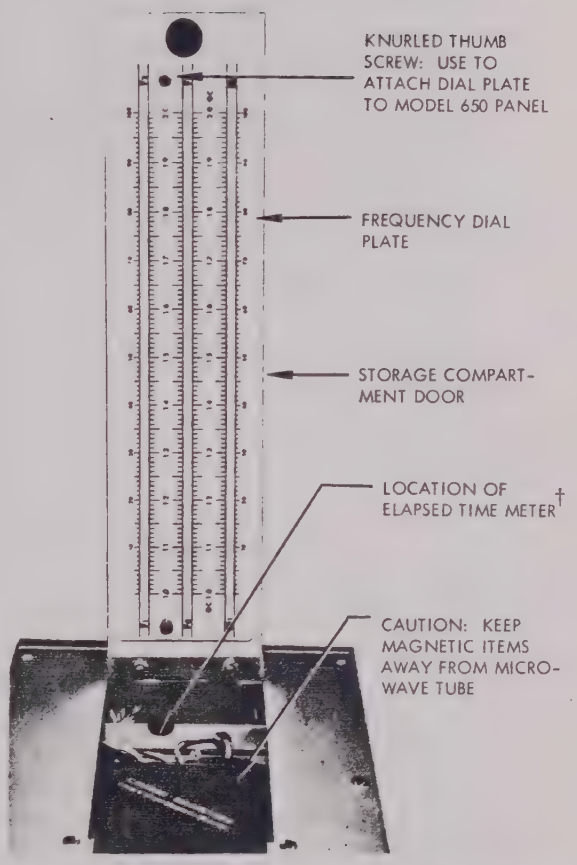

KNURLED THUMB SCREW: USE TO ATTACH DIAL PLATE TO MODEL 650 PANEL
FREQUENCY DIAL PLATE
STORAGE COMPARTMENT DOOR
LOCATION OF ELAPSED TIME METER†
CAUTION: KEEP MAGNETIC ITEMS AWAY FROM MICROWAVE TUBE

FIGURE 2-1. TOP VIEW OF TYPICAL OSCILLATOR PLUG-IN UNIT SHOWING STORED POSITION OF FREQUENCY DIAL PLATE.

NOTE: Be sure the proper frequency dial plate, corresponding to the plug-in unit installed, is used. When the Model 650 is shipped with an aluminum shipping plate installed in the dial plate area, or if a different plug-in is to be used, install and calibrate the frequency dial plate stored in the top storage compartment (Figure 2-1) of the plug-in unit to be used, as described above. To remove and install plug-in units, and/or for access to the dial plate storage compartment, remove the plug-in unit by turning the LOCK knob fully CCW. When a plug-in unit is reinstalled, the LOCK knob must be turned CW only after the plug-in unit is pushed all the way in; otherwise the interlock switch associated with the locking device will keep the instrument off.

†Not used on units having 1-yr BWO tube warranty.

INCOMING INSPECTION TEST.

CAUTION

ANY INTERNAL ADJUSTMENTS LOCATED WITHIN HE MODEL 650 CHASSIS ARE CRITICAL. THEY HAVE EN CAREFULLY FACTORY-ADJUSTED PRIOR TO HIPMENT AND SHOULD NOT NEED FIELD ADJUST-ENT. BECAUSE OF THE INTERACTION OF THESE DJUSTMENTS A COMPLETE REALIGNMENT MAY BE QUIRED IF THEY ARE DISTURBED. REFER TO SEC-ON 5 OF THIS MANUAL BEFORE TOUCHING ANY DJUSTMENTS.

llowing inspection test may be performed prior to regular tion of the Model 650. In each step, leave switch settings de previously unless instructed otherwise.

FREQUENCY CHECK.

ake the following panel control settings:

EQUENCY Mode Selector to SINGLE
NGLE Frequency Selector to F_0
ODULATION Selector to AM OFF
OUTPUT switch to UNLEVELED
WER LEVEL control to MAXIMUM clockwise position
FREQUENCY indicator to the low-end frequency on the dial
rn POWER switch to ON.

OTE: A time delay relay delays application of high ltage for approximately 60 seconds after the power switch turned on. This is to allow a brief warm-up period for microwave oscillator tube filament. If the ac power is for even an instant, the normal 60-second delay will cur before the high voltage returns after turn-on.

nnect the RF OUTPUT connector through a suitable fre-ency meter and attenuator pads to a video detector. nnect the detector output to the vertical channel of an cilloscope. Set the scope for self-triggering.

CAUTION

E RF POWER OUTPUT CAN BE AS GREAT AS 300 MW NO UNITS) OR 10 W (VTM UNITS). DO NOT EXCEED E MAXIMUM POWER RATING OF THE DETECTOR. ITABLE PADS SHOULD BE USED TO REDUCE THE OUT-T POWER AND THUS PROTECT THE DETECTOR.

eck the frequency by observing the drop of the scope ce as the frequency meter is moved through the output quency. Repeat the check using several F_0 settings oss the band. The reading on the frequency meter should within 1% of the frequency indicated on the dial. If not, er to Section 5 for recalibration.

SWEEP VOLTAGE CHECK.

ake the following panel control settings:

EQUENCY Mode Selector to SWEEP; $F_1 \rightarrow F_2$
EEP TIME to .01 seconds; and concentric VARIABLE Control fully clockwise (CAL position).
EEP TRIGGER Selector to LINE.

nnect an oscilloscope to the SWEEP OUTPUT jack using coupling. The signal observed should be a sawtooth h an amplitude of exactly 15 volts peak-to-peak.

RF OUTPUT CHECK.

ke the following panel control settings:

F_1 FREQUENCY indicator to 0 (low end of scale).
F_2 FREQUENCY indicator to 100 (high end of scale).
FREQUENCY RETRACE to OFF.

b. Connect a video detector to the RF OUTPUT connector using suitable pads, as in 2.7.1, and connect the detector output to the vertical channel of an oscilloscope.

c. Connect the SWEEP OUTPUT jack to the horizontal deflection channel of the oscilloscope.

d. Visually check the unleveled rf output across the band.

2.7.4 LEVELER CHECK IN "K" OR "AK" TYPE UNITS. (For other units, skip to 2.7.5.)

a. Set the RF OUTPUT switch to LEVELED, and the RF SAMPLER switch to INTERNAL.

b. Observe the rf output with an oscilloscope connected as in 2.7.3.

c. Rotate the POWER LEVEL control counterclockwise until the rf output is leveled, at which time the UNLEVELED light will go out.

d. Visually check the leveled rf output across the band.

2.7.5 MODULATION CHECK.

a. Make the following panel control settings:

MODULATION Selector to SQ WAVE

b. Observe the rf output with an oscilloscope connected as in 2.7.3. The display should be keyed on and off in a symmetrical square wave pattern.

2.7.6 TRIGGER CHECK

a. Turn the TRIGGER Selector switch to FREE RUN.

b. Observe the output with an oscilloscope connected as in 2.7.3. The automatic sweep should continue.

c. Turn the TRIGGER Selector switch to MANUAL.

d. Press the button in the TRIGGER Selector switch. One sweep should be obtained after each push of the button.

2.8 STORAGE OF PLUG-IN UNITS REMOVED FROM THE MODEL 650. Always store the Oscillator Plug-in unit in a suitable container, such as the ALFRED Storage Container, Model 9000, or on wood and at least six inches from magnetic sources.

2.9 RETURNING THE INSTRUMENT. If it becomes necessary to return the instrument to ALFRED ELECTRONICS, authorization must first be obtained from our Sales Department.

When authorization is received, prepare the instrument for shipment by removing the frequency dial plate from the panel and placing it in the storage compartment of the plug-in unit. Then install the plug-in unit in the Model 650 and secure with four shipping screws installed through the holes marked by arrows in the bottom and rear of the cabinet. A protective shipping plate or a piece of cardboard should be placed over the dial plate area for protection. A board or heavy cardboard buffer should be placed in front of the unit across the handles to protect the panel from blows against the container.

The instrument should be wrapped in a protective material such as polyethylene and heavy wrapping paper to protect against marring by the padding used in the container. A sufficient quantity of padding material, such as hair flex, should be placed all around the instrument for cushioning. If the

original shipping container is not available, an equivalent rugged cardboard container or wooden crate should be used for the packing carton. Pack the instrument so that it cannot move around in the container. A letter containing all pertinent information should be included in the package, unless such a letter has previously been sent to our Sales Department.

SECTION 3 - OPERATION

3.1 FRONT PANEL CONTROLS (See Figure 3-1).

A functional description of all front panel controls is given in Table 3-1. In the table, CW and CCW are used to abbreviate clockwise and counterclockwise, respectively.

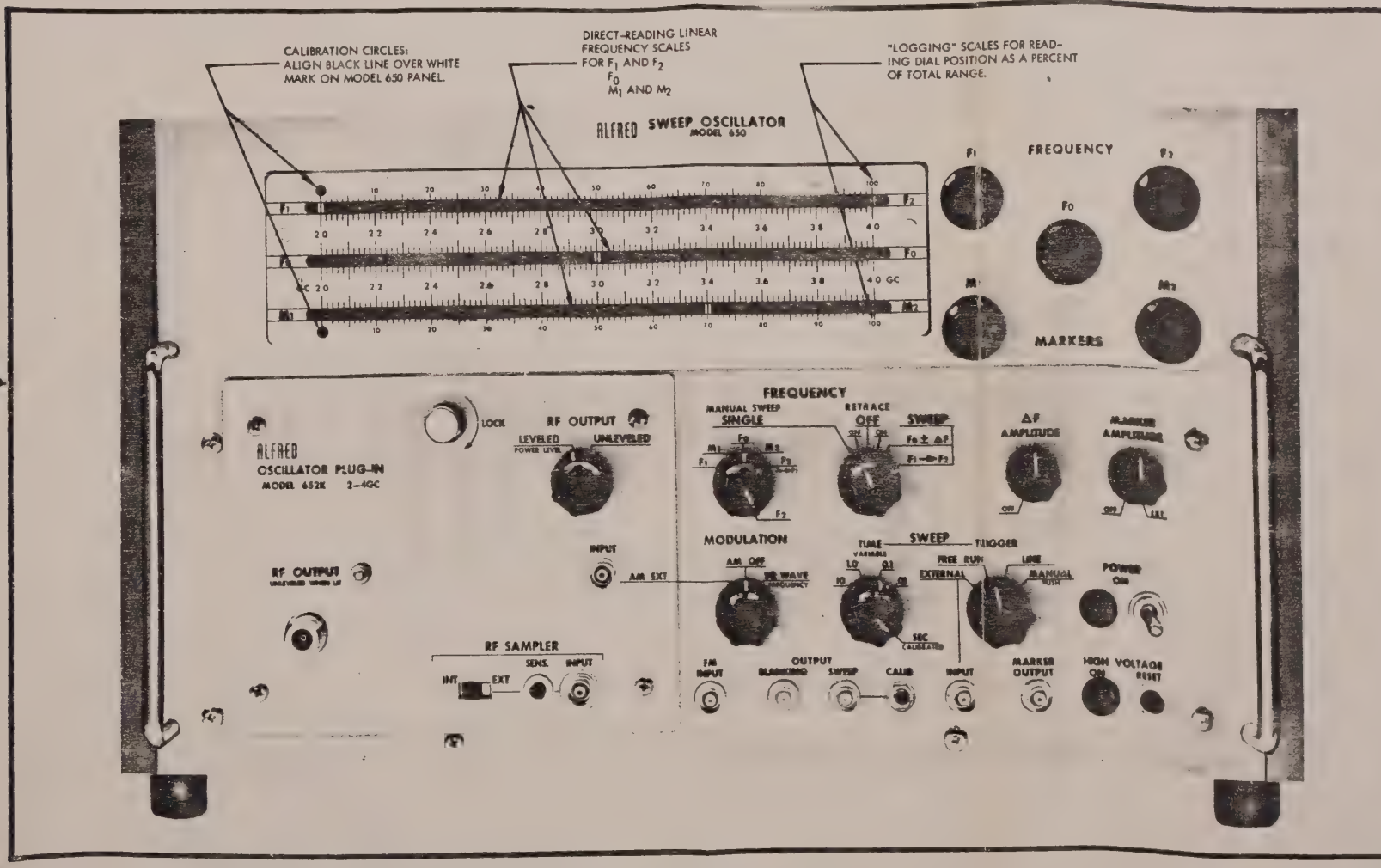


FIGURE 3-1. FRONT PANEL

Table 3-1. Description of Front Panel Controls and Indicators

Control or Indicator	Function
FREQUENCY Controls SINGLE-OFF-SWEEP Mode Selector Switch	In $F_1 \rightarrow F_2$ SWEEP position, provides a swept rf output starting at the F_1 frequency indicator setting and sweeping to the F_2 frequency indicator setting. The sweep speed and recurrence are controlled by other panel controls. The sweep frequency range (from F_1 to F_2) can be varied from 100% to 2% of the frequency band of the Oscillator Plug-in unit by use of the F_1 and F_2 FREQUENCY controls. When in this mode, marker pips are available at the F_0, M_1 and M_2 frequency settings. A sawtooth sweep voltage of +15 V amplitude is available at the SWEEP OUTPUT jack. The SWEEP light glows while each sweep progresses from F_1 to F_2. In $F_0 \pm \Delta F$ SWEEP position, the rf output is swept symmetrically about any F_0 frequency setting (starting at $F_0 - \Delta F$ and sweeping to $F_0 + \Delta F$). ΔF can be varied from 0 to ± 5% of the full frequency band by using the ΔF AMPLITUDE control. This narrow sweep mode may be used to examine small perturbations seen when using the $F_1 \rightarrow F_2$ mode, by setting F_0 to the perturbation frequency and switching to $F_0 \pm \Delta F$ mode. When in this mode, marker pips are available at the M_1 and M_2 settings, and the +15 V sawtooth is available at the SWEEP OUTPUT jack. The SWEEP light glows while each sweep progresses from $F_0 - \Delta F$ to $F_0 + \Delta F$. In OFF position, applies a modulating signal to the microwave oscillator tube, to turn off the rf output power. In single-frequency operation, the OFF position can be used to zero external meters and establish a zero power reference. In all modes of operation, the OFF position can be used to keep the instrument in a "standby" condition. By maintaining filament and cathode voltages during this "standby" condition, the microwave oscillator tube is continuously being outgassed. This tends to extend tube operating life by more than 10%. In SINGLE position, the oscillator output can be any one of five single frequencies determined by the F_0, F_1, F_2, M_1 or M_2 FREQUENCY and MARKER controls. The SINGLE Frequency Selector switch selects any one of the above frequencies for rf output.
RETRACE Selector Switch (Red)	Concentric with the Mode Selector switch, this switch is operative only in the swept-frequency modes of operation. In the OFF position, rf power output is removed during retrace; in the ON position, rf power is supplied during retrace.
SINGLE Sweep Frequency Selector Switch	This switch is operative only in the single-frequency mode of operation. It selects one of the FREQUENCY or MARKER controls to set the output frequency (F_0, F_1, F_2, M_1, or M_2).
MANUAL SWEEP Control (Red)	This control functions only when the SINGLE Sweep Frequency Selector switch is in the F_2 position. Concentric with that switch, this control can be turned clockwise to manually sweep the rf output from F_1 to F_2. At the extreme counterclockwise position, the output frequency is F_1. At the extreme clockwise position, the control actuates a switch which locks the output frequency at F_2.
FREQUENCY Dial Control Knobs F_1 and F_2	In the $F_1 \rightarrow F_2$ sweep mode, these controls select the lower and upper limits respectively, of the sweep. In single-frequency mode, they can be used to select output frequencies for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting of each control is shown by the corresponding indicator bar in the frequency dial (F_1 to the left of F_2 in the $F_1 - F_2$ dial slot). Not operative in $F_0 \pm \Delta F$ sweep mode.
F_0	In $F_0 \pm \Delta F$ sweep mode, selects the center frequency about which the narrow symmetrical sweep is made. In $F_1 \rightarrow F_2$ sweep mode, and during manual sweep in the F_2 single-frequency mode, provides an absorptive marker pip (if adjusted to a frequency within the swept range). In single-frequency mode, can be used to select an output frequency for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting is shown by the F_0 dial indicator bar.
MARKERS Control Knobs M_1 and M_2	In $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweep modes, and during manual sweep in the F_2 single-frequency mode, these controls provide adjustable absorptive marker pips (if adjusted to a frequency within the swept range). In single-frequency mode, can be used to select two output frequencies for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting of each control is shown by the corresponding indicator bar in the frequency dial (M_1 to the left of M_2 in the $M_1 - M_2$ dial slot). NOTE: In single-frequency mode, the rf output may be swept manually by turning the FREQUENCY or MARKERS control selected by the SINGLE Sweep Frequency Selector switch.
ΔF AMPLITUDE Control	In the $F_0 \pm \Delta F$ sweep mode, adjusts the width of the symmetrical sweep about F_0. Provides maximum sweep width (± 5% of the full frequency band) in the fully clockwise position. Sweep width decreases to zero as the control is turned counterclockwise to OFF at the extreme CCW position, to provide fixed-frequency output at F_0. NOTE: The OFF position is at the CCW rotation limit; it is not a switched position.
MARKER AMPLITUDE Control	In the $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweep modes, and during manual sweep in the F_2 single-frequency mode, sets the amplitude (absorptive peak height) of the rf markers that are visible in the swept rf output. The adjustment range provides maximum amplitude at the clockwise limit (before being switched to the EXT position). The EXT switch position at the CW limit of travel removes the marker pips from the rf output signal and makes available video marker pulses at the MARKER OUTPUT connector. These video marker pulses are negative-going pulses with a -1 V amplitude and a width of 5 μs. One pulse is supplied when the sweep crosses, M_1, M_2, and F_0. (Marker pulses are also supplied during retrace.) The OFF position at the CCW limit of travel turns off all marker signals. NOTE: The OFF position is at the CCW rotation limit; it is not a switched position.

Table 3-1. (Continued)

Control or Indicator	Function
DULATION Controls MODULATION Mode elector Switch	In SQ WAVE position, modulates the rf output with an internally-generated square wave which is adjustable in frequency betwen 800 and 1200 cps by means of the concentric red Frequency Vernier Control. Square-wave modulation amplitude is 0 to power level set for all leveled units, all 650C Series units, and all 650 Series units above 12.4 Gc; and 0 to full-on for all 650 Series units below 12.4 Gc. In AM EXT position, the rf output will be turned off until an external signal is applied. A +10 V signal applied to the AM EXT INPUT connector will turn on the rf signal output to the level set when operation is in leveled mode, and to the maximum output level during unleveled operation. (Higher levels are required for pulsed on-off control; see Paragraph 3.10.2.) In AM OFF position, eliminates all amplitude modulation. Frequency modulation can be used with this or any other position of the switch.
requency Vernier Control Red)	Concentric with the MODULATION Mode Selector switch, this control adjusts the frequency of the internal square-wave modulation in the SQ WAVE modulation mode. Modulation frequency varies between about 800 cps in the full counterclockwise position to about 1200 cps in the full clockwise position.
EP Controls WEEP TIME Selector Switch	Selects the time required to sweep from the start frequency to the stop frequency in either automatic sweep mode ($F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$). With the red vernier control fully clockwise in the CALIBRATED position, the SWEEP TIME positions read directly in seconds (.01, 0.1, 1.0 and 10 seconds).
weep Time Vernier ontrol (Red)	Concentric with the SWEEP TIME Selector switch. When fully clockwise, calibrates that switch to read in seconds. When rotated counterclockwise out of the CALIBRATED position, slows the sweep to increase the sweep time by a factor up to about 10:1 at the fully CCW position. Allows a maximum sweep time of 100 seconds and continuous adjustment between all fixed sweep time settings. NOTE: The CALIBRATED position is at the CW limit of rotation; it is not a switched position.
WEEP TRIGGER Selector witch	In EXTERNAL position, a positive pulse signal applied to the EXTERNAL INPUT jack is required to trigger each sweep. Pulse amplitude must be at least +5 V, and pulse width must be at least 10 microseconds. In FREE RUN position, a new sweep is triggered immediately upon the completion of each sweep. Thus, the sweep is recurrent with a period equal to the SWEEP TIME setting. In LINE position, the sweep trigger is synchronized to the power line frequency. In MANUAL position, each sweep must be triggered by pressing the concentric button.
Manual Trigger Pushbutton Red)	Concentric with the SWEEP Trigger Selector switch. Press to trigger a sweep in the MANUAL sweep mode. Not operative in other sweep modes.
WER ON Toggle Switch	Turns power on when switched up; removes all power from the instrument when switched down. Adjacent POWER ON indicator glows when the instrument is energized.
H VOLTAGE RESET Pushbutton	Press to reset high voltage after correcting overload condition.
H VOLTAGE ON Light	Glows when high voltage is applied to microwave oscillator tube. When instrument is first turned on, there is a time delay of about 60 seconds before high voltage is applied.
OUTPUT Selector Switch (on Oscillator Plug-in)	Selects LEVELED or UNLEVELED operation. For leveled operation, external sampling inputs must be applied in the 650 and 650A Series plug-in units.
OWER LEVEL Control (Red)	Concentric with RF OUTPUT Selector switch. Sets output power level during leveled operation in all units, and during unleveled operation in the 650A, 650AK, 650C, and 650CK Series. Provides maximum power when fully clockwise; reduces output to the level that permits full-band leveling when turned to a mid-position, and then an additional 5 db (most plug-in units) when turned fully counterclockwise (10 db on C- and CK- Series).
LEVELED WHEN LIT Light (on Oscillator Plug-in)	Glows when rf output is unleveled. In leveled operation, glows when power is unleveled over any portion of the band being swept, indicating that the POWER LEVEL setting is too high, or the (external) sampler output is too low.
AMPLER SENS Screwdriver ntrol (on Oscillator Plug-in)	When using an external rf leveling sampler, this control permits adjustment of the internal leveling amplifier sensitivity to match the external sampler output for optimum broadband leveling; see Paragraph 3.12.3. CAUTION USE ONLY NON-METALLIC SCREWDRIVER TO MAKE ANY ADJUSTMENTS ON PLUG-IN. FERROUS MATERIALS CAN DAMAGE THE MICROWAVE TUBE.
WER LEVEL Control (Black) (only on Oscillator Plug-in units with output frequency above 12.4 Gc)	Adjacent to waveguide output flange on units with output frequency above 12.4 Gc. Operates waveguide flap attenuator to adjust output power level over a range of about 10 db in all modes of operation.
SAMPLER Snap Switch (only on Oscillator Plug-in units with internal sampling)	Selects INTernal or EXTernal sampling for leveled operation. For EXTernal sampling, the input from the external detector must be applied to the RF SAMPLER INPUT connector.

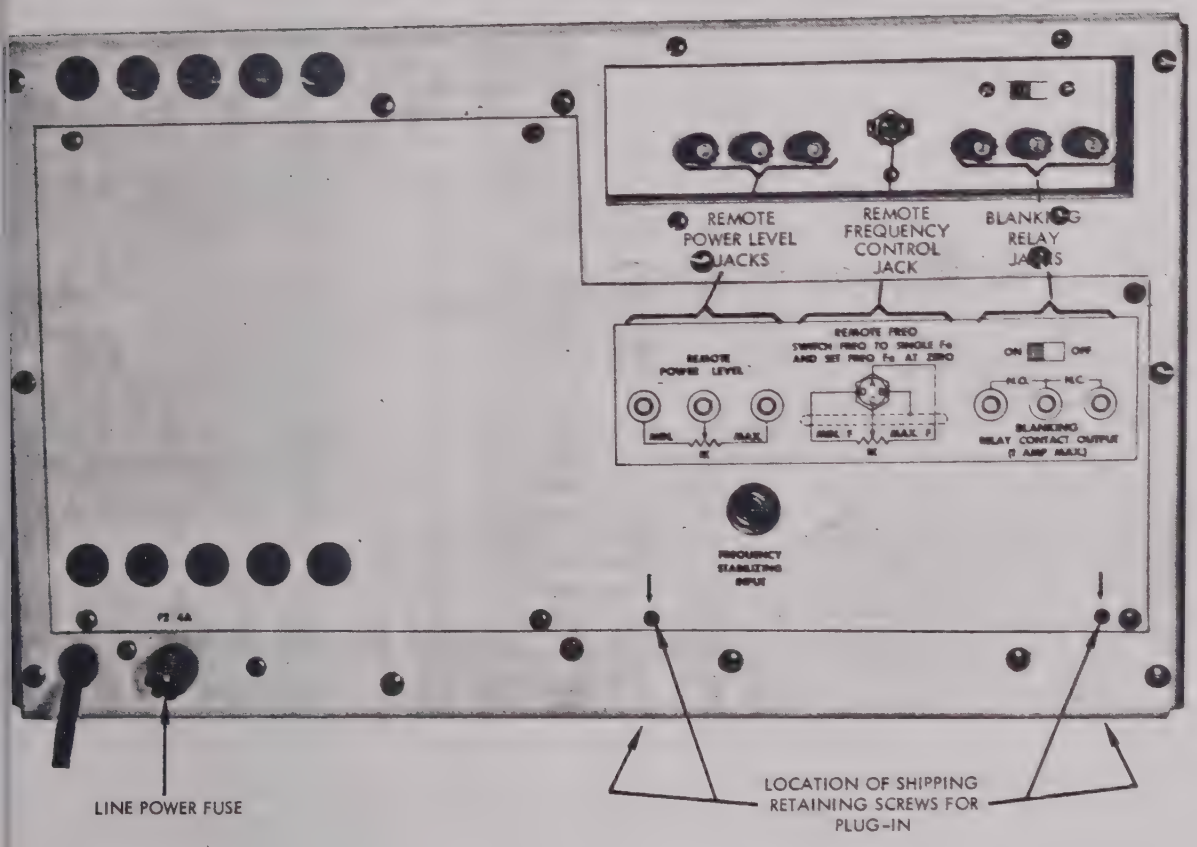


FIGURE 3-2. REAR PANEL

3.2 FRONT PANEL CONNECTORS (See Figure 3-1).

A functional description of all front panel connectors is given in Table 3-2.

Table 3-2. Description of Front Panel Connectors

Connector	Function
AM INPUT	Permits deviation of the rf output signal from the frequency set by the panel controls by using an externally-applied signal. A signal of 15 V peak-to-peak is sufficient to deviate the output over the full frequency range. Response is dc to 10 Kc. Input impedance is 15 K ohms.
BLANKING OUTPUT	Provides a +50 V signal during sweep retrace. Output impedance is 10 K ohms.
SWEEP OUTPUT	Provides a 0 to +15 V sawtooth synchronized with the rf output frequency in either swept or fixed-frequency modes. Output impedance is 10 K ohms. In the $F_1 \rightarrow F_2$ swept output mode, the sawtooth wave tracks the rf output, and is 0 volts at F_1, increasing to +15 V at F_2. In the $F_0 \pm \Delta F$ swept mode, the sawtooth runs the full 0 to +15 V range linearly as the rf output sweeps from $-\Delta F$ to $+\Delta F$. In the single-frequency modes, the output is a dc level linearly proportional to the dial frequency (0 V at low end; +15 V at high end) when M_1, F_0, or M_2 control the frequency output. In the F_2 single-frequency mode (during manual sweep), the output level varies linearly from 0 at a frequency corresponding to F_1 to +15 V at a frequency corresponding to F_2. In the F_1 single-frequency mode, no output is provided. NOTE: The sweep output level is switched to +15 V to permit calibration of the using device when the adjacent CALIB pushbutton is pressed.
EXTERNAL (TRIGGER) INPUT	Permits use of an external trigger signal to trigger each rf output sweep. A signal of +5 V minimum, with a duration of at least 10 μs, actuates the sweep. Input impedance is greater than 10 K.
MARKER OUTPUT	Supplies marker output pulses when the rf output frequency crosses the value set by each FREQUENCY MARKER control (M_1, M_2, and F_0) in any swept mode of operation. The pulses have a -1 V amplitude and a width of 5 μs. Output impedance is 1 K ohm. They are supplied only when the MARKER AMPLITUDE control is turned fully CW to the EXT switched position.
AM EXT (on Oscillator Plug-in)	Permits input of an external signal to amplitude-modulate the rf output, when the MODULATION Selector switch is in the AM EXT position. In that mode, the rf output will be turned off until an external modulation signal is applied. A +10 V signal will turn on the rf output to the set level in leveled operation or to the maximum level in unleveled operation. For high speed pulse modulation control, a signal of about +100 V peak is required to drive the ac coupling circuit which applies the input directly to the microwave tube. Input impedance is about 2 K ohms shunted by 100 pf. Pulse modulation response is 0.1 μs for full-range on-off in unleveled operation; 10 μs with solid-state leveling and 20 μs with grid-leveling.
RF SAMPLER INPUT (on Oscillator Plug-in)	Permits connection of a signal from an external sensing coupler and detector to drive the leveling circuits. A detector input of approximately -100 mv, corresponding to rated rf power output, is required for optimum performance. Input impedance is 2800 ohms.
RF OUTPUT Coax or Waveguide Connector	Supplies the Sweep Oscillator output signal.

3.3 REAR PANEL CONTROLS AND CONNECTORS (See Figure 3-2).

A functional description of all rear panel controls and connectors is given in Table 3-3.

Table 3-3. Description of Rear Panel Controls and Connectors

Control or Indicator	Function
REMOTE POWER LEVEL Banana Jacks	Permits connection of an external 1 K potentiometer to provide remote power level control during leveled operation. (See Paragraphs 3.10.3 and 3.12.4 for details.)
REMOTE FREQ 4-Terminal Connector	Permits connection of an external 1 K potentiometer in a shielded circuit to provide remote frequency control. (See Paragraph 3.11.2 for details.)
BLANKING RELAY CONTACT OUTPUT Banana Jacks	Provides S. P. D. T. relay contact operation during sweep retrace on the two slowest sweep ranges. Both normally-open (N.O.) and normally-closed (N.C.) contacts are available to permit use for recorder pen lift control, etc. The contacts have a maximum capacity of 1 amp.
ON OFF BLANKING Snap Switch	When in OFF position, keeps the blanking relay (described above) de-energized. When in ON position, allows the blanking relay to be energized during sweep retrace.
FREQUENCY STABILIZING INPUT (on Oscillator Plug-in with BWO tube)	Permits connection of a signal from an external discriminator for frequency- or phase-locking the oscillator output at any desired single frequency. The input should not exceed ± 50 V (+ increases frequency). Input impedance is 10 K ohms. (See Paragraph 3.11.3 for details).

INSTRUMENT TURN-ON PROCEDURE

heck that the line cord is plugged in and properly grounded.
heck that the desired plug-in unit has been inserted and
icked into position in the plug-in opening in the Model
50, and that the frequency dial plate for that plug-in
is been removed from its storage compartment in the
lug-in and placed in the calibrated position on the panel,
described in Paragraph 2-6.
rn the FREQUENCY Mode Selector switch to OFF.
rn the POWER toggle switch ON.
e POWER ON indicator light should glow immediately.
not, check that the plug-in LOCK knob is properly
ghtened (it actuates an interlock switch).
ter about 60 seconds, the HIGH VOLTAGE ON light should
ow. The instrument is now ready to provide rf output.
rn to the appropriate paragraph(s) below for the control set-
gs and operating procedures for the desired mode of operation.

CAUTION

When changing Plug-in units, turn the POWER switch
off and wait 15 seconds before removing the installed
Plug-in unit and inserting the other Plug-in unit, to
permit decay of the power supply voltages. Then
repeat the above turn-on procedure.

NOTE

The FREQUENCY Mode Selector switch removes the rf
output when placed in the OFF position, and keeps the
instrument in "standby" condition ready for instant use.
Thus, the FREQUENCY Mode Selector switch may be
placed in the OFF position until output connections are
completed, and during "warmup" periods and other
downtime. RF OUTPUT is instantly restored when the
FREQUENCY Mode Selector switch is set to any other
position.

OPERATING PROCEDURES FOR SWEPT-FREQUENCY OUTPUT MODES.

GENERAL. The Model 650 can be operated in either
-frequency or fixed frequency modes of operation. In
-frequency operation, the sweep can be either automati-
or manually controlled, using panel controls or remote
ol signals. There are two automatic sweep modes: the
lband ($F_1 \rightarrow F_2$) sweep and the narrow-band ($F_0 \pm \Delta F$) sym-
cal sweep. In many situations the broadband sweep will
ed for quick-look testing over a large portion of the band,
he narrow-band sweep can be used to examine areas of
est discovered in the broadband sweep. The ALFRED
el 650 Series is unique in that the two sweep modes are set
independent controls, so that operation can be switched
kly from one to the other by simply switching the FRE-
NCY Mode Selector switch.

e are two manual sweep modes: one in which the selected
le" frequency is swept by manually turning its frequency
ol knob, and another in which the MANUAL SWEEP con-
drives the sweep between preset limits.

BROADBAND ($F_1 \rightarrow F_2$) SWEEP OPERATION

.1 BASIC DATA. In the broadband sweep mode of oper-
, the frequency can be swept over all or any portion of the
ency range of the unit, as determined by the selected start
ency (F_1) and stop frequency (F_2) points. The sweep is
ys made in the direction of increasing frequency. The
to sweep from F_1 to F_2 can be varied from 10 milliseconds to 100 seconds. During the forward sweep an auxiliary sweep output voltage varying from 0 to +15 V is available for use in driving the horizontal axis of an oscilloscope or recorder. The sweep can be triggered by several alternate means, and the rf output can be either on or off during the retrace interval (after F_2 is reached and until the next sweep is triggered). Various modulation options and marker pips are available. Auxiliary blanking signals are available during retrace. The SWEEP light glows for the duration of each $F_1 \rightarrow F_2$ forward sweep.

3.5.2.2 DETAILED PROCEDURE. For broadband sweep operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$.
RETRACE (red) switch to ON or OFF depending on whether rf output is wanted on or off during the retrace interval between sweeps.
FREQUENCY F_1 Dial Control to desired sweep start frequency.
FREQUENCY F_2 Dial Control to desired sweep stop frequency.
Set SWEEP TIME and SWEEP TRIGGER controls to obtain desired sweep response (see Paragraphs 3.7 and 3.8).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP sawtooth and BLANKING signals, see Paragraph 3.15.

NOTE: To examine a point of interest observed during the broadband sweep mode, adjust the F_0 control (which operates a marker during $F_1 \rightarrow F_2$ sweep) until its marker is on the point of interest; then switch the FREQUENCY Mode Selector to $F_0 \pm \Delta F$ and the narrow-band sweep (see Paragraph 3.5.3) will automatically be centered on that point.

3.5.3 NARROW-BAND ($F_0 \pm \Delta F$) SYMMETRICAL OPERATION.

3.5.3.1 BASIC DATA. In this mode, a center frequency (F_0) can be set anywhere in the band and the rf is swept symmetrically about this point with a maximum sweep range of ± 5% of the full frequency range. The center frequency can be moved during operation by turning the F_0 control, to allow quick adjustment of the area being examined to any desired point. Sweep time control settings set the time to sweep from $-\Delta F$ to $+\Delta F$. Other control arrangements and auxiliary output signals are essentially the same as in the broadband sweep, except that only two markers are available because the F_0 control (which positions a marker in $F_1 \rightarrow F_2$ sweep) is used to control the sweep center frequency. The same 0 to +15 V dc sweep output is supplied to drive a recorder or scope horizontal axis during the sweep from $-\Delta F$ to $+\Delta F$. Thus, when the operating mode is switched from broadband to narrow-band sweep, this output permits automatic expansion of the display to fill the same horizontal length. The SWEEP light glows for the duration of each forward sweep from $F_0-\Delta F$ to $F_0+\Delta F$.

3.5.3.2 DETAILED PROCEDURE. For narrow-band symmetrical sweep operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$.
RETRACE (red) switch to ON or OFF depending on whether

rf output is wanted on or off during the retrace interval between sweeps.
FREQUENCY F_0 Dial Control Knob to desired center frequency of narrow-band sweep.
ΔF AMPLITUDE Control to a position corresponding to the desired sweep frequency range, up to a maximum of ± 5% of the full instrument band. (See NOTE below.)
Set SWEEP TIME and SWEEP TRIGGER Controls to obtain desired sweep response (see Paragraph 3.7 and 3.8).
If markers are desired - see Paragraph 3-13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP sawtooth and BLANKING signals, see Paragraph 3.15.

OTE: To change the center frequency or sweep width, the and ΔF controls can be adjusted at any time. ΔF remains nstant as F_0 is adjusted, unless the ΔF AMPLITUDE control is o adjusted. To calibrate the sweep width obtained with the F AMPLITUDE control, set the M_1 and M_2 markers to the sired sweep limits above and below F_0. Then turn the ΔF MPLITUDE control to the point where the markers appear at e sweep limits. (See Paragraph 3.13.)

5.4 MANUAL SWEEP USING MANUAL SWEEP CONTROL.

5.4.1 BASIC DATA. In this mode, the rf output can be ept over all or any portion of the full frequency range of the strument, as determined by the start frequency point (F_1) and e stop frequency point (F_2). The sweep position between ese two points is controlled by the position of the MANUAL WEEP Control, and the sweep may therefore be made in either rection, (or back-and-forth) and at any desired rate. The dc veep output provided in this mode has the same frequency dependence as in the $F_1 \rightarrow F_2$ automatic sweep, varying linearly om 0 to +15 V as the sweep is manually driven between F_1 nd F_2. This feature makes this mode especially convenient r use with recorder readout, since it permits precise frequency sitioning with the same horizontal axis calibration as provided automatic sweep. While the manual sweep back from F_2 to can be considered a "retrace," there is no rf blanking available and no auxiliary blanking output during this mode. The veep time and triggering controls are non-functional in this ode, but markers, modulation, and auxiliary dc sweep output re available.

.5.4.2 DETAILED PROCEDURE. For manual sweep operation sing the MANUAL SWEEP Control, turn the instrument on as escribed in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
SINGLE Frequency Selector to F_2.
FREQUENCY F_1 Dial Control Knob to desired low-frequency end of sweep.
FREQUENCY F_2 Dial Control Knob to desired high-frequency end of sweep.
MANUAL SWEEP (red) Control: turn as desired to electronically sweep the signal between F_1 (at its counterclockwise limit) and F_2 (at its switched clockwise limit).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP dc signal, see Paragraph 3.15.

NOTE: If the MANUAL SWEEP Control is turned fully CW to its switched F_2 position, the output frequency can then be swept and monitored on the frequency dial by turning the FREQUENCY F_2 Control Knob. To monitor specific frequency points when the MANUAL SWEEP control is operating the sweep (with no indication on the frequency dial), the markers can be utilized.

3.5.5 MANUAL SWEEP USING FREQUENCY CONTROL KNOBS.

3.5.5.1 BASIC DATA. In this mode, the rf output can be swept over all or any part of the full frequency range without using preset start and stop points, and controlled by any one of the FREQUENCY or MARKERS controls. The instantaneous frequency output can thus be monitored on the frequency dial. The other operating features are the same as in the manual sweep mode using the MANUAL SWEEP control, except that markers are available only when the FREQUENCY F_2 Control is used to control the sweep.

3.5.5.2 DETAILED PROCEDURE. For manual sweep operation using the FREQUENCY Control Knobs, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
SINGLE Frequency Selector to any position (corresponding to the Control Knob to be used for sweeping the output signal).
FREQUENCY or MARKERS Control Knob selected by the above setting of the SINGLE Frequency Selector: turn as desired to sweep the rf output signal in any desired manner; output frequency is indicated by the corresponding indicator bar on the frequency dial.
MANUAL SWEEP (red) Control to its switched F_2 position (not required unless F_2 is used).
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output leveling is not desired - turn RF OUTPUT switch to UNLEVELED.
If markers are desired (F_2 Control Mode only) - see Paragraph 3.13.
If markers are not desired in F_2 Control Mode - turn MARKER AMPLITUDE Control of OFF limit of rotation.
If it is desired to use optional OUTPUT SWEEP signal, see Paragraph 3.15.

NOTE: When F_1, F_2, M_1 or M_2 Control Knobs are selected for sweep control, the unused knob which shares the same dial indicator slot should be turned to the corresponding band edge so as not to interfere with the Control Knob and indicator bar being used.

3.6 OPERATING PROCEDURES FOR SINGLE-FREQUENCY OUTPUT MODE.

3.6.1 GENERAL DATA. The instrument can be used to generate fixed (single) frequency rf output that is either unmodulated (CW) or modulated. The output frequency is determined by any

e five frequency indicators (F_0, F_1, F_2, M_1, or M_2) as by a front panel switch; and the frequency indicators nuously adjustable to provide any desired frequencies e instrument range. The frequencies can be changed ted as desired during operation. For fixed-frequency where only one single frequency is required, the which Control Knob to select is arbitrary. In many wever, it will be convenient to be able to switch etween up to five pre-selected frequencies which are channel limits or other points of interest. In that etting the five frequency indicators to the different es in the order F_1 - M_1 - F_0 - M_2 - F_2, it will be o quickly select them in sequence by turning the Frequency Selector switch.

F frequency modulation is to be used with single-fre- eration, disregard the following procedure and in- ow the procedure of Paragraph 3.5.3.1 for $F_0 \pm \Delta F$ urn the ΔF AMPLITUDE control fully CCW to its OFF tation, and the F_0 control to the desired single fre- This procedure must be used because the FREQUENCY ector switch must be set to a SWEEP position to elim- rnal ac feedback which would interfere with fm mod- External frequency stabilization can be used with the single-frequency operating procedure (see Paragraph or details).

TAILED PROCEDURE. For fixed-frequency operation, strument on as described in Paragraph 3.4 and make tings as follows:

ENCY Mode Selector to SINGLE.
ENCY and MARKERS Control Knobs: turn one or controls as desired to select one or more output fre- cies for selection by the SINGLE Frequency Selector h. If several frequencies are desired, the mechanical ation of the frequency dial will require F_2 to be above nd M_2 to be above M_1. If it is desired to switch be- n frequencies in ascending or descending order, the ators used for the various frequencies should be n in the same sequence as the positions of the SIN- Frequency Selector (F_1 - M_1 - F_0 - M_2 - F_2).
Frequency Selector to the position corresponding to al indicator set at the desired rf output frequency.
R AMPLITUDE Control to its OFF limit of rotation equired unless F_2 is used).
AL SWEEP (red) Control to its switched F_2 position equired unless F_2 is used).
rude modulation is desired - see Paragraph 3.9.
rude modulation is not desired - turn MODULATION to AM OFF.
t leveling is desired - see Paragraph 3.12.
leveling is not desired - turn RF OUTPUT switch LEVELED.
frequency stabilization using an external frequency se-locking device is desired - see Paragraph .1.

y or all of the frequencies can be adjusted at any use by turning the Control Knobs. The output fre- be "swept" by adjusting the Control Knob for the in use.

TION OF SWEEP TIME.

TIME Selector switch controls the time required for to progress from the start frequency (F_1 or $F_0 - \Delta F$, depending on mode) to the stop frequency (F_2 or $F_0 + \Delta F$). It provides four calibrated positions when the red VARIABLE control is tuned to its clockwise CALIBRATED end position. When the VARIABLE control is turned counterclockwise out of the CALIBRATED position, it slows the sweep by a variable amount which increases to 10:1 at the extreme counterclockwise end. Thus, a continuously adjustable sweep time range from .01 sec. to 100 sec. is available by proper adjustment of the SWEEP TIME and VARIABLE controls.

The .01 and .1 second ranges are most convenient for oscilloscope display; the 1.0 second range for small strip chart recorder readout; and the 10 second range for X-Y recorder readout. The 100 second sweep can be used for special applications such as measurement of output power or modulation characteristics with external meters.

3.8 SELECTION OF SWEEP TRIGGER MODE.

The SWEEP TRIGGER Selector switch positions provide four types of sweep triggering: automatically recurring sweeps triggered either from the LINE or in a FREE RUN mode; MANUAL triggering; or EXTERNAL control of triggering.

Automatically recurring sweeps are most convenient for oscilloscope display. The LINE triggering mode is useful in systems where display or other equipment is line-synchronized; otherwise the FREE RUN mode can be used.

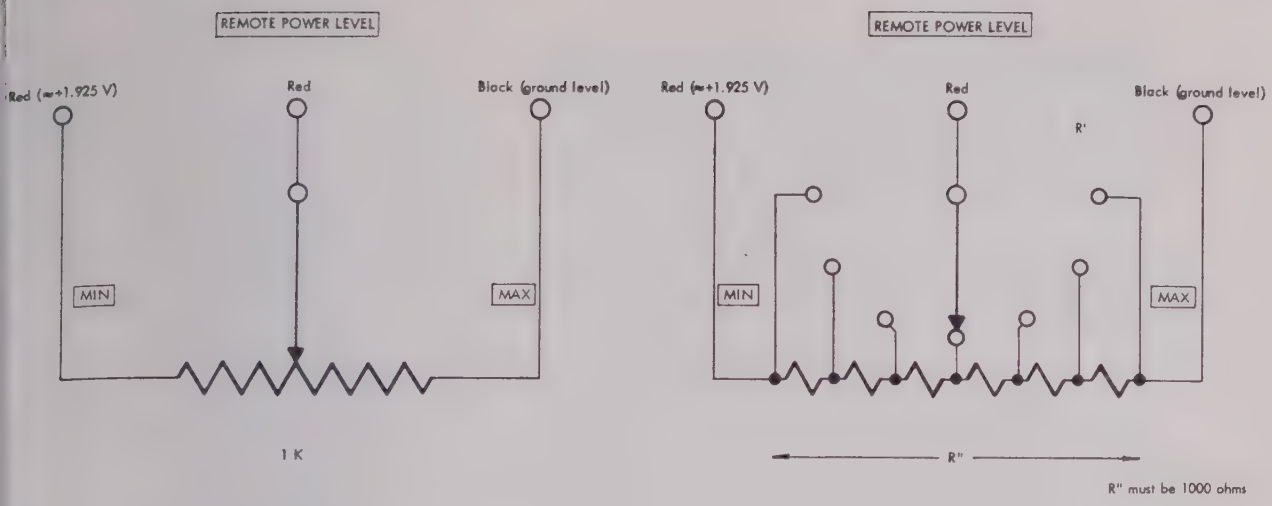
Non-recurring sweep is most convenient for recorder readout, so that just one trace can be triggered after the readout equipment is set-up and calibrated. In the MANUAL switch position, one sweep is triggered each time the red PUSH button is pressed.

The EXTERNAL triggering mode can be used for either automatically recurring or one-shot non-recurring sweeps synchronized with external equipment. In this mode, a signal of at least +5 V with a duration of at least 10 microseconds applied to the EXTERNAL INPUT connector will trigger a sweep (provided that the previous sweep has been completed). Trigger signals received prior to completion of the previous sweep will be disregarded. Thus a pulse train with any convenient PRF can be used for triggering and synchronizing recurrent sweeps with external equipment if each individual pulse meets the above specifications. For triggering individual sweeps, a single pulse or a positive step-voltage of at least +5 V can be used. Input impedance is greater than 10 K ohms.

3.9 MODULATING THE RF OUTPUT.

The rf output can be either amplitude modulated (using an external signal or the internal square wave) or frequency modulated (using external signals). Modulation of either type can be used in single-frequency and swept modes of operation, and can be obtained with low-level signal voltages which need not exceed 15 V. The front panel MODULATION switch allows selection of either external (AM EXT) or internal (SQ WAVE) amplitude modulation (ON-OFF type only), or no amplitude modulation (AM OFF). In the AM OFF position, (or either of the other positions if combined modulation is desired), frequency modulation can be obtained by applying a suitable signal to the front panel FM INPUT connector or the rear panel REMOTE FREQ connector, and variable-level amplitude modulation can be obtained by connecting a variable resistance to the REMOTE POWER LEVEL jacks.

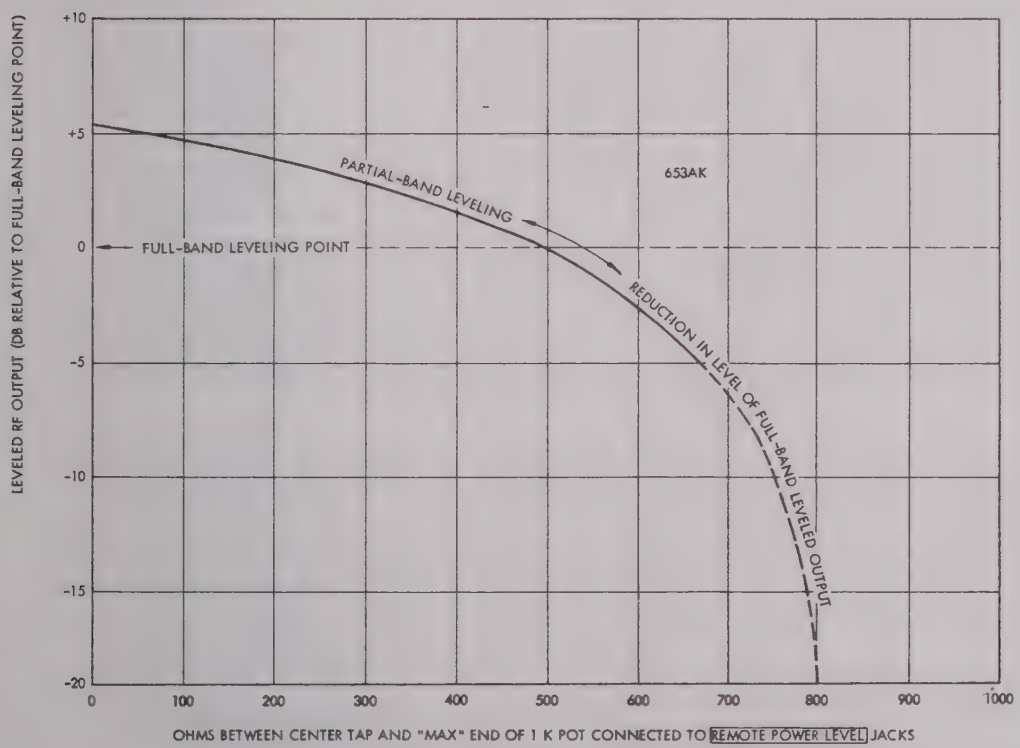
Each of these modulation modes is discussed separately below. The amplitude modulation modes are discussed under Paragraph



A. Circuit Using External Potentiometer

B. Circuit Using Switched Resistive Network

NOTE: ON BWO UNITS, THE OUTPUT LEVEL DECREASES TO THE FULL-BAND LEVELING POINT AND THEN AT LEAST AN ADDITIONAL 5 DB AS THE WIPER OF THE 1 K POTENTIOMETER IS MOVED FROM THE "MAX" TO "MIN" LIMIT. A SWITCHED RESISTOR NETWORK PROVIDES SIMILAR RESPONSE. ON SOME UNITS, THE CONTROL RANGE IS GREATER THAN 6 DB. THE RED POWER LEVEL CONTROL ON THE FRONT PANEL MUST BE TURNED FULLY CLOCKWISE TO ENABLE THE MAXIMUM CONTROL RANGE WITH THE REMOTE POWER LEVEL JACKS. THE FRONT PANEL CONTROL CAN BE USED TO REDUCE THE OUTPUT TO THE LEVELING POINT FOR THE SWEEP RANGE USED. THEN THE REDUCED-RANGE REMOTE ADJUSTMENT WILL BE UNIFORMLY BELOW THE LEVELED VALUE. VTM UNITS WITH SOLID-STATE LEVELING HAVE SIMILAR RESPONSE. ON VTM UNITS WITHOUT SOLID-STATE LEVELING, REMOTE POWER LEVEL CONTROL WILL REDUCE THE OUTPUT LEVEL TO THE FULL-BAND LEVELING POINT, AND UP TO 1 DB ADDITIONAL.



NOTE: FOR ACCURATE CONTROL OF A PARTICULAR PLUG-IN UNIT, A SIMILAR INDIVIDUAL CURVE SHOULD BE PLOTTED FOR THAT UNIT.

C. Graph Of Typical Response To Resistance Connected To REMOTE POWER LEVEL Jacks

FIGURE 3-3. REAR PANEL CONNECTIONS FOR EXTERNAL POWER LEVEL PROGRAMMING OR AMPLITUDE MODULATION WITH LEVELED OUTPUT

equency modulation under Paragraph 3.11.

LITUDE MODULATION.

ITERNAL (SQUARE WAVE) AMPLITUDE MODULA-

is type of modulation is convenient for use in mea-
stems which have an audio-frequency measurement
h as most reflectometer and ratio meter set-ups. For
ations, turn the MODULATION Selector to SQ
adjust the red Frequency Vernier Control to its mid-
on to obtain an output modulation frequency of
cps (the standard for most systems). The Frequency
trol permits varying the modulation frequency from
o 1200 cps when turned clockwise through its range
This can be used to set the modulating frequency
response with any measurement system. The stabil-
uare wave frequency is better than 0.2% per hour
ly even temperature environment.

al square-wave modulation, 100% modulation is
that the rf output is either full-on (to pre-set level
cable) or off during each half-cycle of the square
ng the off portion of the square wave, the tube is
nd beam cut-off, so that the ON to OFF ratio is
the LEVELED condition the rise and fall time is
μs between the 10% and 90% power points; UN-
sponse is even faster. The symmetry ratio between
OFF portions of the square wave is between .95
he use of square wave modulation does not shift the
quency, nor does it degrade the excellent rf output
ability in single-frequency modes.

ERNAL "ON-OFF" AMPLITUDE MODULATION.
modulation extends the versatility of the instrument
ny special applications ranging from simple exter-
control by an external source to high-speed pulse
When the MODULATION selector is turned to the
ition, the rf output is turned off until a positive
lied to the AM EXT INPUT connector. A +10 V
he microwave tube ON, and when the voltage
+6 V the tube is turned off. This modulation is of
F type and the on to off ratio is infinite. (This
le is intended only for ON-OFF type modulation
it operates digital control circuits. If variable-
ntrol is desired, it should be obtained by means of
ed to the REMOTE POWER LEVEL jacks, as
Paragraph 3.10.3.

fall time, when in the leveled condition, is better
ith solid-state leveling and 20 μs with grid level-
n the unleveled condition, rise and fall time is
high-speed pulsed rf operation, with the output in
d condition, it is possible to obtain rise and fall
us if a pulse generator is used to drive the AM EXT
The pulse generator should have a 50-ohm output
nd should be capable of supplying at least +100 V
ac coupling circuit connecting directly to the
ube) with a rise and fall time better than .02 μs.
650 Plug-in units require less than the +100 V as
ove. (For the exact value, check the Instruction
he particular plug-in involved.) The input imped-
EXT AM input is approximately 2 K Ω shunted by

ERNAL VARIABLE-LEVEL AMPLITUDE MODULA-
Figure 3-3.) This mode can be used to obtain
odulation with any desired modulation factor up to
io of 10 db or greater. Since this mode makes use of the leveling circuits, the best pulse response rise and fall time is about 10 μs. This type of modulation is available while operating with the rf output in the leveled condition, with either internal or external sampling. With leveled rf output, variable-level amplitude modulation (or remote output level programming) is available through resistive network connections to the REMOTE POWER LEVEL banana jacks in the rear. The procedure is given below:

For this mode, the controls must be set for internal or external leveling operation as described in Paragraph 3.12, and the red POWER LEVEL control must be turned fully clockwise. Then modulation of the output level can be obtained by connecting a 1 K potentiometer or an equivalent resistive network between the three REMOTE POWER LEVEL banana jacks on the rear panel, as shown in Figure 3-3. As the center red terminal connection is adjusted across 1 K resistance between the MAX and MIN jacks, the power level will decrease to the full-band leveling point and then at least 5 db below that level. An overall reduction of maximum power level in this mode can be obtained by turning the front panel POWER LEVEL control, CCW; but when this control is turned out of the fully clockwise position, the control range available from the REMOTE POWER LEVEL jacks will be reduced. While the main purpose of these terminals is to permit remote control of the output level, rather than amplitude modulation, a motor-driven potentiometer or switched network can be used to apply modulation through this circuit. Read Paragraph 3.12.4 for additional data.

3.11 FREQUENCY MODULATION.

The Model 650 Series Sweep Oscillators provide three modes of frequency modulation and/or external frequency control, each of which has its own input jack(s) and a specific application. The separate jacks are the FM INPUT front panel jack, and the REMOTE FREQ and FREQUENCY STABILIZING INPUT rear panel jacks. (The FREQUENCY STABILIZING INPUT jack is provided on BWO plug-in units only. It is located on the rear of the plug-in unit, and is accessible through an opening in the Model 650 rear panel.)

For most fm modulation applications, the FREQUENCY Mode Selector switch must be in a SWEEP position to eliminate internal ac feedback which would tend to oppose frequency variations. Single-frequency operation for application of fm can be obtained by leaving the sweep untriggered and/or setting ΔF to zero in the $F_0 \pm \Delta F$ swept mode.

The FM INPUT jack is used for frequency-modulating or sweeping the rf output signal by means of applied signal voltages. The REMOTE FREQ jack is used to permit remote adjustment or programming of the rf output frequency by means of an adjustable potentiometer or resistive network. The FREQUENCY STABILIZING jack is used to obtain ultra-stable single-frequency output by coupling in feedback error signals from a frequency discriminator or phase detector. Each of these modes is discussed separately below.

3.11.1 VOLTAGE-CONTROLLED FM USING THE FM INPUT JACK (See Figures 3-4, 3-5, and 3-6).

3.11.1.1 GENERAL DATA. With either swept or single-frequency output, the rf signal can be frequency modulated by applying a signal to the FM INPUT jack. The frequency of the applied modulating signal can be from dc to 10 Kc. With frequency modulation, the instantaneous rf output frequency will be the sum of the frequency called for by the panel controls,

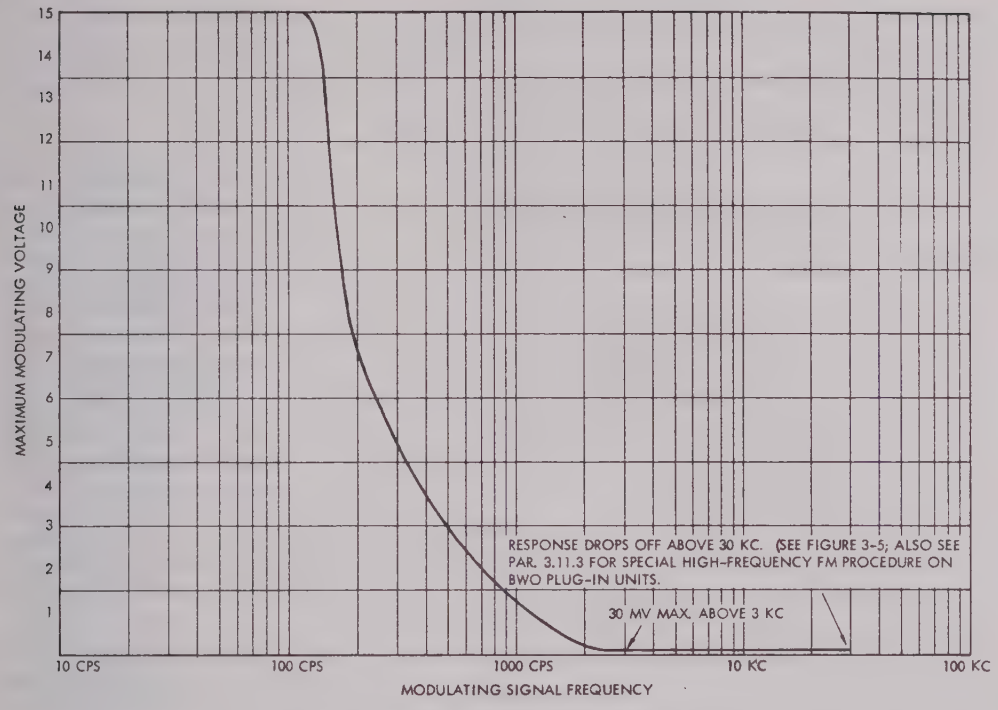


FIGURE 3-4. MAXIMUM ALLOWABLE MODULATING VOLTAGE VS MODULATING SIGNAL FREQUENCY FOR LARGE-SIGNAL FM MODULATION AT FM INPUT JACK

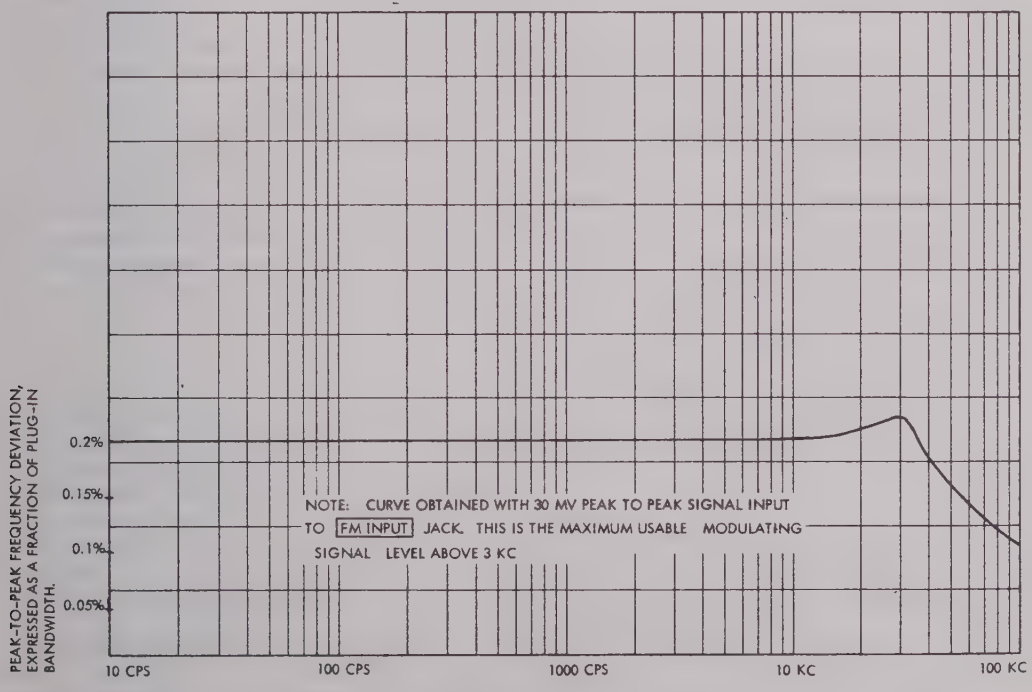

PEAK-TO-PEAK FREQUENCY DEVIATION, EXPRESSED AS A FRACTION OF PLUG-IN BANDWIDTH.
0.2%
0.15%
0.1%
0.05%
NOTE: CURVE OBTAINED WITH 30 MV PEAK TO PEAK SIGNAL INPUT TO FM INPUT JACK. THIS IS THE MAXIMUM USABLE MODULATING SIGNAL LEVEL ABOVE 3 KC
10 CPS
100 CPS
1000 CPS
10 KC
100 KC

FIGURE 3-5. MODULATION RESPONSE VS MODULATING SIGNAL FREQUENCY FOR SMALL-SIGNAL FM MODULATION AT FM INPUT JACK

...-scale or down-scale adjustment called for by the ...odulation. For single-frequency operation, the ...wept mode is used with ΔF set to zero and F_0 at the ...equency. With the F_0 control set at the low end of ...n single-frequency operation, a signal of +15 V ... the FM INPUT jack will drive the output frequency ...h end.

... is linear, with an output signal of less than +15 V ... a proportional fraction of a full-range upscale fre... ...ring. Modulating signals of negative polarity can ...be used to drive the output frequency below that set ...nel controls. The amount of deviation obtainable by ...n of a particular modulating voltage is thus propor... ...he bandwidth between the frequency limits of the ... It is equal to the voltage expressed as a fraction of ...s the plug-in bandwidth. Maximum deviation obtain... ...igh use of the FM INPUT jack is limited by both the ... of the modulating signal (which determines how fast ...t be deviated) and the rf output frequency range of ...n (which determines how much deviation a given ...oduces). The relationship of permissible modulating ... the modulating signal frequency is shown in Figures ...and 3-6. Higher-frequency response (which is also ...r) can be obtained in BWO plug-in units by applying ...n directly to the helix as described in Paragraph 3.11.3.

...N: The rf output can never be driven beyond the band' ...uencies shown on the plug-in panel without distortion, ...cation of excess voltage in an attempt to drive the fre... ...iyond the high limit of the band may damage the micro... ...

...iscussions in this section are in terms of the nominal ...5 V control range. Due to mechanical limitations in ...echanism, the instrument is factory-calibrated to pro... ...ull frequency output range in response to a slightly ...oltage range, typically + 0.15 V to +14.75 V corres... ...o the range between 0 and 100 on the dial logging ...here absolute accuracy is required in remote control ...ns, the exact FM INPUT voltage values corresponding ...-range swing should be determined by actual measure... ...substituted in the equations. In most cases, the use of ... V will produce an error of less than 1%.

... FREQUENCY-MODULATING A SINGLE-FRE... ... OUTPUT. To frequency-modulate a single-frequency ...or to externally drive a swept-frequency output from ... starting frequency, proceed as follows:

...he following switch settings:

...ENCY Mode Selector to SWEEP $F_0 \pm \Delta F$.
...CE switch to ON.
...PLITUDE Control to OFF limit of rotation.
... TRIGGER Selector to MANUAL (so that no internal ...p is triggered; do not push the PUSH button).
...ENCY F_0 Control Knob to set the desired starting ...uency for fm or externally driven sweep.
...simultaneous amplitude modulation is desired - turn ...ULATION control to AM OFF.
...taneous amplitude modulation is desired - see Para... ...n 3.10.
...ers are not desired - turn MARKER AMPLITUDE con... ...o OFF limit of rotation.
...ers are desired - see Paragraph 3.13.
...t leveling is desired - see Paragraph 3.12.

...ate the signal amplitude to be applied to the FM ... jack to achieve the desired frequency modulation, ...ne following equations:

1) Instantaneous rf output frequency increment, Δf, due to applied modulating voltage:

$$\Delta f = \frac{\text{instantaneous modulating voltage}}{+15} \times \left[\begin{array}{l}\text{instrument}\\ \text{frequency}\\ \text{range in Gc}\end{array}\right]$$

where the instrument frequency range in Gc = (highest dial frequency)-(lowest dial frequency). Note that Δf can be positive or negative, depending on the polarity of the modulating signal.

2) Instantaneous output frequency, F_{output}, due to the combination of internal and external signals:

$F_{output} = \Delta f$ + indicated single-frequency dial setting.
or
$\Delta f = F_{output}$ - indicated single-frequency dial setting.

NOTE: To sweep the entire band, set the F_0 frequency indicator to the low end of the band and apply a 0 to +15V sweep at the FM INPUT jack. If the dial-set output frequency is above the low end of the band, Δf must be reduced accordingly by reducing the modulation voltage, to keep F_{output} within the usable band.

Example A

Conditions:
- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Indicated frequency = 4.7 Gc (F_0 set to 4.7 Gc)
- Instantaneous modulating voltage = + 5 volts

Calculations:
1) Instantaneous frequency increment, Δf: $\Delta f = 5/15 \times 4$ Gc $= 1/3 \times 4$ Gc $= 1.33$ Gc
2) Instantaneous output frequency = 1.33 Gc + 4.7 Gc = 6.03 Gc

Example B

Conditions:
- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Indicated frequency = 4.7 Gc (F_0 set to 4.7 Gc)
- Instantaneous modulating voltage = -5 V

Calculations:
1) Instantaneous frequency increment, Δf: $\Delta f = -5/15 \times 4$ Gc $= -1/3 \times 4$ Gc $= -1.33$ Gc
2) Instantaneous output frequency = -1.33 Gc + 4.7 Gc = 3.37 Gc

Thus, it can be seen that a +5 V signal applied to the fm input jack produces an instantaneous frequency of 6.03 Gc, which falls within the frequency limits of the unit (4 to 8 Gc) but the instantaneous frequency produced by the -5 V signal is below the minimum frequency, and will produce distorted output.

Example C

Conditions:
- Plug-in unit range = 8 to 12.4 Gc; therefore frequency range = (12.4 - 8.0) Gc = 4.4 Gc
- Desired starting frequency for externally driven sweep = 9.3 Gc (set F_0 to 9.3 Gc).
- Desired sweep top frequency = 11.7 Gc

Calculations:
1) Determine the required maximum output frequency increment, Δf, to be produced by the modulating signal to drive from the start frequency to the top frequency, using the F_{output} equation: $\Delta f = (11.7 - 9.3)$ Gc $= 2.4$ Gc

2) Determine the required maximum modulating signal level to achieve the desired sweep frequency increment, using the Δf equation:

$$2.4 \text{ Gc} = \frac{V_{mod}}{15} \times 4.4 \text{ Gc}$$

(simplify by dividing both sides by 4.4 Gc and multiplying both sides by 15)

$$15 \times \frac{2.4}{4.4} = V_{mod} = +8.2 \text{ volts}$$

Thus, to obtain a linear sweep, a signal varying from 0 to +8.2 volts would be required.

Example D

Conditions:
- Plug-in unit range = 1 to 2 Gc; therefore, frequency range = (2 - 1) Gc = 1 Gc
- Indicated frequency = 1.5 Gc (F_0 set to 1.5 Gc)
- Desired shifted output frequency = 1.05 Gc

Calculations:

1) Determine the output frequency increment, Δf, to obtain the desired frequency-shift performance, using the F_{output} equation:

$\Delta f = (1.05 - 1.5)$ Gc = -0.45 Gc
Note that the minus sign denotes a frequency decrease.

2) Determine the required modulating signal voltage to achieve the desired frequency shift, using the Δf equation:

$$\Delta f = \frac{V_{mod}}{15} \times 1 \text{ Gc} = -0.45 \text{ Gc}$$

$$V_{mod} = -0.45 \times 15 = -6.75 \text{ volts}$$

Example E

Conditions:
- Plug-in unit range = 7 to 12.4 Gc; therefore frequency range = (12.4 - 7) Gc = 5.4 Gc
- Indicated frequency = 10.5 Gc (F_0 set to 10.5 Gc)
- Desired rf deviation: ± 1.5 Gc

NOTE: A cursory check shows that this is within the frequency range of the instrument, since the maximum and minimum frequencies produced by the deviation are 9 Gc and 12 Gc.

Calculations:

1) Determine the required peak-to-peak frequency deviation, Δf: $\Delta f = 2 \times 1.5$ Gc = 3.0 Gc

2) Determine the required peak-to-peak signal level for an ac signal to produce the desired deviation, using the Δf equation:

$$3.0 \text{ Gc} = \frac{V_{mod}}{15} \times 5.4 \text{ Gc}$$

(Simplify)

$$V_{mod} = 15 \times \frac{3.0}{5.4}$$

V_{mod} = 8.33 volts (peak-to-peak).
Therefore an ac signal of ± 4.16 volts amplitude is required.

c. Apply the proper signal calculated in Step b. to the FM INPUT jack.

NOTE: The frequency of the modulating signal must be within the limits given by Figures 3-4, 3-5, and 3-6. The applied voltage must not be sufficient to drive the output frequency outside the range of the plug-in. Violation of either of these rules will produce distorted output.

3.11.1.3 EXTERNALLY DRIVEN FREQUENCY SWEEP. Refer to Paragraph 3.11.1.2 and Figure 3-6.

3.11.1.4 FREQUENCY MODULATION IN SWEPT-FREQUENCY MODES. An externally-driven sweep or single frequency offset can be added to an internal sweep established by the panel controls, using the following procedure:

a. Make the following switch settings:

FREQUENCY Mode Selector to either SWEEP Mode ($F_0 \pm \Delta F$ or $F_1 \rightarrow F_2$).
RETRACE switch to ON.
FREQUENCY F_1, F_2, or F_0 Control Knobs, and ΔF AMPLITUDE Control - set as appropriate for sweep mode selected (see Paragraph 3.5).
If internal sweep is to be synchronized with the modulating signal - set SWEEP TRIGGER Selector to EXTERNAL and apply a suitable external signal in accordance with Paragraph 3.8.
If internal sweep is to be independent of the modulating signal - set SWEEP TRIGGER Selector to FREE RUN, LINE, or MANUAL (see Paragraph 3.8).
SWEEP TIME Control - set for desired sweep response (see Paragraph 3.7).
Unless simultaneous amplitude modulation is desired - turn MODULATION Control to AM OFF.
If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling is desired - see Paragraph 3.12.

b. Calculate the signal amplitude to be applied to the FM INPUT jack to achieve the desired modulation, using the basic equations given above in 3.11.1.2 b. Consider the limiting conditions that will occur at the high-frequency and low-frequency limits of the sweep due to both the internal and external signals. Select modulation voltages that will not drive the rf output outside the frequency range of the plug-in.

Example A

Conditions:
- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Indicated sweep mode and limits: $F_1 \rightarrow F_2$, with F_1 = 4.5 Gc, F_2 = 6.5 Gc
- Desired rf deviation: ± 0.5 Gc

NOTE: This is the greatest available deviation for the above conditions, since the -0.5 Gc swing at the low end of the sweep will drop the output frequency to the 4.0 Gc lower limit of the plug-in.

Calculations:

1) Determine the required peak-to-peak frequency deviation, Δf:

$\Delta f = 2 \times 0.5$ Gc = 1 Gc

2) Determine the required peak-to-peak signal level for an ac signal to produce the desired deviation, using the Δf equation:

$$1\ Gc = \frac{V_{mod}}{15} \times 4\ Gc$$

(simplify by dividing both sides by 4 Gc and multiplying both sides by 15)

$$15 \times \frac{1}{4} = V_{mod}$$

V_{mod} = 3.75 volts (peak-to-peak).

Therefore, an ac signal of ± 1.875 volts amplitude is required.

ple B

Conditions:

- Plug-in unit range = 8 to 12.4 Gc; therefore frequency range = (12.4 - 8.0) Gc = 4.4 Gc
- Indicated sweep mode and limits: $F_0 \pm \Delta F$, with F_0 set at 10.2 Gc and ΔF set to maximum (approximately ± 0.22 Gc)
- Desired external frequency control: Step the narrow-band center frequency F_0 to 9.0 Gc and 11.5 Gc.

NOTE: A cursory check shows that this is within the frequency range of the instrument, since the over-all minimum and maximum limit frequencies as the output varies from -ΔF to +ΔF will be 8.78 Gc and 11.72 Gc.

Calculations:

1) Determine the frequency deviation, Δf, required for each of the center-frequency steps, using the F_{output} equation:

$$\Delta f_1 = (9.0 - 10.2)\ Gc = -1.2\ Gc$$

Note that the minus sign denotes a frequency decrease.

$$\Delta f_2 = (11.5 - 10.2)\ Gc = 1.3\ Gc$$

2) Determine the required modulating signal voltage to achieve each desired frequency shift, using the Δf equation:

$$\Delta f_1 = \frac{V_{mod}}{15} \times 4.4\ Gc = -1.2\ Gc$$

(simplify)

$$V_{mod} = \frac{-1.2}{4.4} \times 15 = -4.099 \text{ volts for } \Delta f_1$$

$$\Delta f_2 = \frac{V_{mod}}{15} \times 4.4\ Gc = 1.3\ Gc$$

(simplify)

$$V_{mod} = \frac{1.3}{4.4} \times 15 = 4.432 \text{ volts for } \Delta f_2$$

the proper signal calculated in Step b. to the FM jack.

: The frequency of the modulating signal must be the limits given by Figures 3-4, 3-5, and 3-6. The d voltage must not be sufficient to drive the output ncy outside the range of the plug-in. Violation of of these rules will produce distorted output.

3.11.2 REMOTE FREQUENCY PROGRAMMING USING THE REMOTE FREQ JACK (See Figures 3-6 and 3-7). The REMOTE FREQ connector on the rear of the instrument can be used for frequency programming using external resistors. When remote frequency programming is used, the rf output frequency will be the frequency called for by the panel controls, increased by the programmed frequency increment. The response time is the maximum time it will take for the frequency to be within the specified tolerance of frequency and residual fm. The minimum response time can be determined from Figure 3-6, using the right-hand vertical scale.

NOTE: Because frequency-stabilizing ac feedback is supplied internally in the SINGLE position of the FREQUENCY Mode Selector switch, a single frequency obtained through this mode should be used for remote frequency programming if a response time slower than 100 milliseconds is satisfactory. If response to program changes must be faster than 100 milliseconds, the symmetrical sweep mode ($F_0 \pm \Delta F$) should be used, with no sweep trigger applied.

For remote frequency programming, the programming potentiometer or resistors must be connected as shown in Figure 3-7. Proceed as follows:

a. Make the following switch settings:

Frequency Mode Selector (see note above) - If response of 100 milliseconds is satisfactory, set to SINGLE and turn SINGLE Frequency Selector switch to F_0. Otherwise, set to SWEEP $F_0 \pm \Delta F$.
RETRACE switch to ON.
ΔF AMPLITUDE Control to OFF limit of rotation.
SWEEP TRIGGER Selector to MANUAL (so that no internal sweep is triggered; do not push the PUSH button).
FREQUENCY F_0 Control Knob to set the desired starting frequency for fm or externally driven sweep.
Unless simultaneous amplitude modulation is desired - turn MODULATION control to AM OFF.
If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE Control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling is desired - see Paragraph 3.12.

b. Calculate the potentiometer wiper position or resistor network values required for connection to the REMOTE FREQ jack. Refer to Figure 3-7 and use the following equations:

1) Rf output frequency shift, Δf, due to programming resistors:

$$\Delta f = \frac{R'}{R''} \times \text{instrument frequency range in Gc}$$

where the instrument frequency range in Gc = (highest dial frequency) - (lowest dial frequency)

NOTE: R" must be 1000 ohms.

Example A

Conditions:

- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Frequency setting = 4.00 Gc (F_0 set to 4.00 Gc)
- R_1 = 427 ohms.

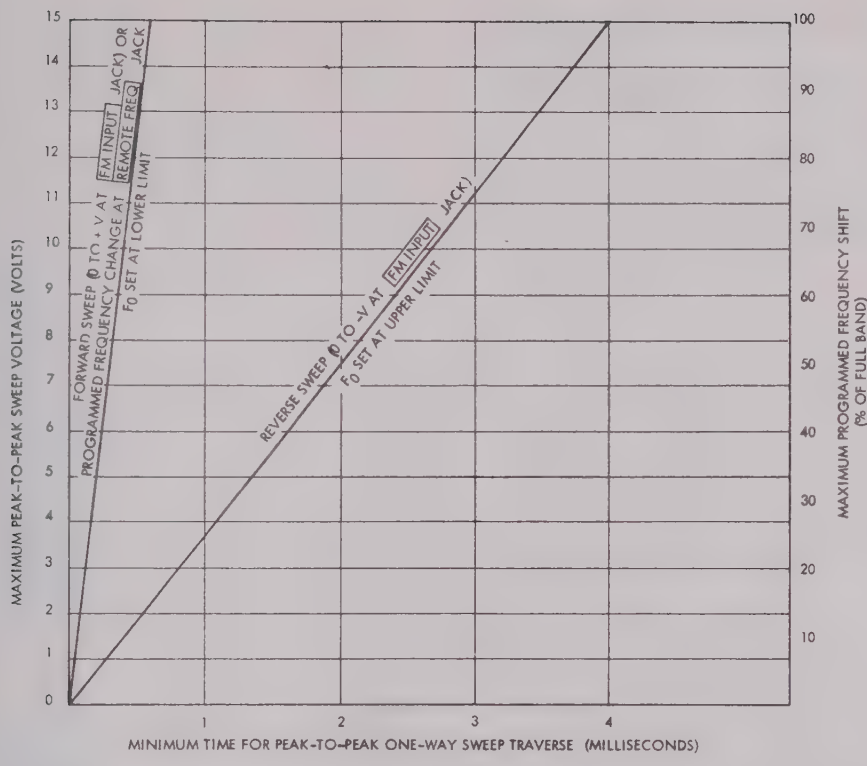
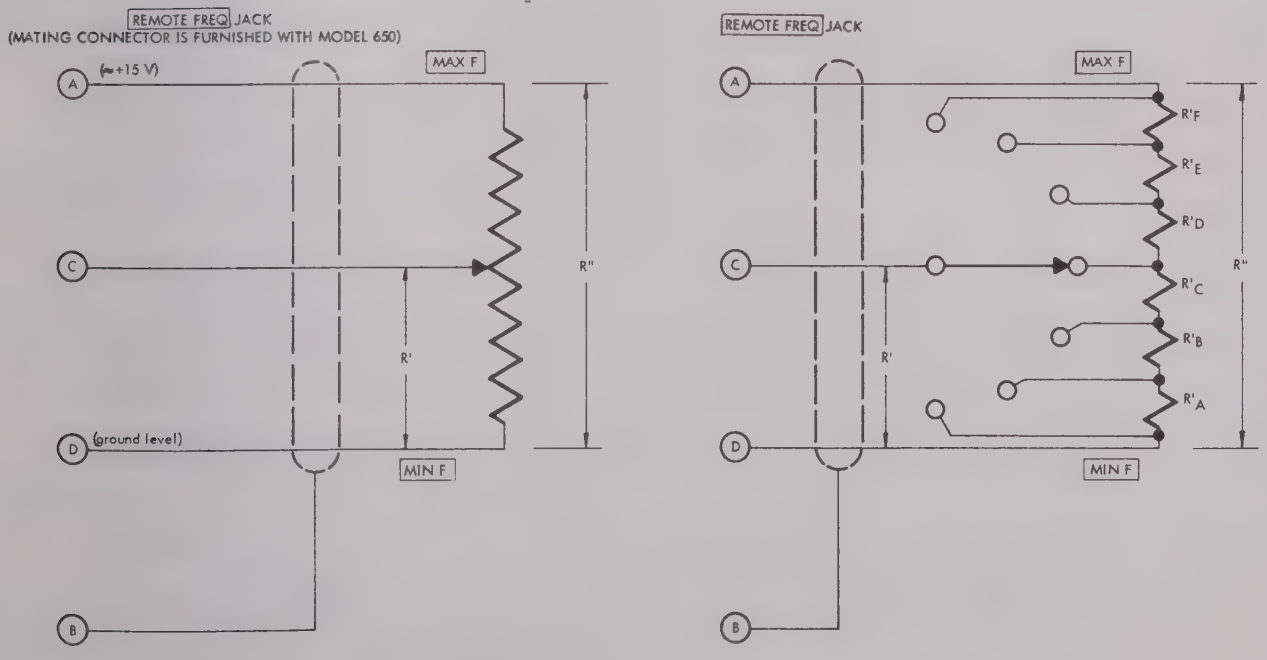

MAXIMUM PEAK-TO-PEAK SWEEP VOLTAGE (VOLTS)
MAXIMUM PROGRAMMED FREQUENCY SHIFT (% OF FULL BAND)
MINIMUM TIME FOR PEAK-TO-PEAK ONE-WAY SWEEP TRAVERSE (MILLISECONDS)
FORWARD SWEEP 0 TO +V AT [F.M INPUT] JACK) OR PROGRAMMED FREQUENCY CHANGE AT [REMOTE FREQ] JACK
F0 SET AT LOWER LIMIT
REVERSE SWEEP 0 TO -V AT [F.M INPUT] JACK)
F0 SET AT UPPER LIMIT

FIGURE 3-6. MAXIMUM FREQUENCY-SHIFT RATE FOR EXTERNALLY-DRIVEN SWEEP OR EXTERNAL FREQUENCY PROGRAMMING



NOTES:

1. R" MUST BE 1000 OHMS.
2. OUTPUT FREQUENCY = $\frac{R'}{1000} \times$ FREQUENCY RANGE + FREQUENCY SET WITH PANEL [F0] CONTROL

A. Continuous Range Programming Using External Potentiometer.

B. Stepped Programming Using Switched Resistive Network.

FIGURE 3-7. REAR PANEL CONNECTIONS FOR REMOTE FREQUENCY PROGRAMMING

Calculations:

1) Rf output frequency shift, Δf:

$$\Delta f = \frac{427}{1000} \times 4 \text{ Gc} - 1.708 \text{ Gc}$$

2) Actual rf output frequency = 1.708 Gc + 4.00 Gc = 5.708 Gc

uple B

Conditions:

- Same as Example A, except frequency setting 7.00 Gc (F_0 set to 7.00 Gc)

Calculations:

1) Rf output frequency shift, Δf, = 1.70 Gc (same as Example A).
2) Actual rf output frequency = 1.708 Gc + 7.00 Gc = 8.708 Gc

rst example the output frequency is less than the upper cy limit of the unit, and the resistor value is acceptable. econd example the resistor value is not acceptable, be- the frequency setting of the panel controls since the ed frequency is greater than the upper frequency limit ug-in unit. Connection of such a resistor would pro- rtortion and possibly damage the microwave tube.

ple C

Conditions:

- Plug-in unit range = 8 to 12.4 Gc; therefore frequency range = (12.4 - 8) Gc = 4.4 Gc
- Frequency setting = 8.5 Gc (F_0 set to 8.5 Gc)
- Desired external programming: step the output frequency to 9.6, 10.8, and 12.0 Gc.

Calculations:

1) Determine the output frequency shift, Δf, required for each step:

$\Delta f_1 = (9.6 - 8.5)$ Gc = 1.1 Gc
$\Delta f_2 = (10.8 - 8.5)$ Gc = 2.3 Gc
$\Delta f_3 = (12.0 - 8.5)$ Gc = 3.5 Gc

2) Determine the corresponding value of R' for each step, using the Δf equation:

$$\Delta f_1 = 1.1 \text{ Gc} = \frac{R'_1}{1000} \times 4.4 \text{ Gc}$$

(simplify by multiplying both sides by 1000 and dividing both sides by 4.4 Gc)

$$R'_1 = 1000 \times \frac{1.1}{4.4} = 100 \times 1/4 = 250 \text{ ohms}$$

$$\Delta f_2 = 2.3 \text{ Gc} = \frac{R'_2}{1000} \times 4.4 \text{ Gc}$$

(simplify)

$$R'_2 = 1000 \times \frac{2.3}{4.4} = 523 \text{ ohms}$$

$$\Delta f_3 = 3.5 \text{ Gc} = \frac{R'_3}{1000} \times 4.4 \text{ Gc}$$

(simplify)

$$R'_3 = 1000 \times \frac{3.5}{4.4} \times 795 \text{ ohms}$$

3) Calculate the values of resistors R_A, R_B, R_C and R_{DEF} to use in the program circuit shown in Figure 3-7.

By reference to Figure 3-7, $R_A + R_B + R_C + R_{DEF} = 1000$ ohms.

$R_A + R_B + R_C = R'_3$ calculated above = 795 ohms

Thus, $R_{DEF} = 1000$ ohms - 795 ohms = 205 ohms
$R_A = R'_1$ calculated above = 250 ohms
$R_B = (R'_2$ above $- R_A) = 523$ ohms - 250 ohms = 273 ohms
$R_C = [R'_3$ above $- (R_A + R_B)]$ = 795 ohms - 523 ohms = 272 ohms

NOTE: The input impedance of the remote programming input is 15 K ohms. Because of this it is required that the total resistance of the external resistors (R') be 1 K ohms. This value is equal to that of the panel frequency controls. If some other value is used, the calibration based on the equations above will not be exact because of the different loading effect of the 15 K input impedance.

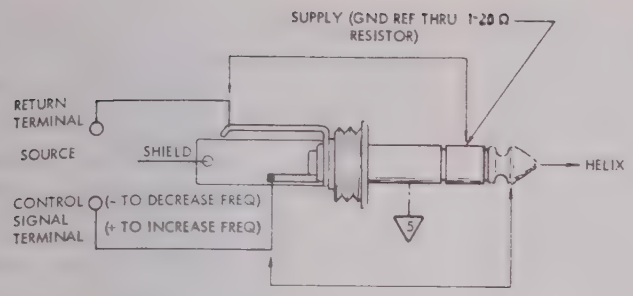
c. Connect the 1 K potentiometer or resistor circuit, set up according to the above calculations, to the REMOTE FREQ jack as shown in Figure 3-7.

3.11.3 REMOTE FREQUENCY STABILIZING AND HIGH FREQUENCY FM MODULATION (BWO PLUG-IN UNITS ONLY) (See Figure 3-8). The FREQUENCY STABILIZING input jack can be used to apply error signals from a frequency discriminator or phase discriminator for frequency - or phase-locking the Model 650 Series in any single-frequency output mode when the FREQUENCY Mode Selector switch is in the SINGLE position. It can also be used to apply high frequency fm in either swept mode, including untriggered sweep to allow fm modulation of single-frequency outputs. Modulating signal frequencies can be higher than those acceptable by the FM INPUT jack. The FREQUENCY STABILIZING input jack is a three-terminal closed-circuit phone jack located on the rear of the plug-in and accessible through a hole in the rear of the Model 650. It provides high frequency response because it applies a modulating voltage directly to the helix lead of the BWO tube. (It therefore is not available on VTM plug-in units.)

For all tubes, the voltage applied to this input should not exceed the limits of +50 volts and -50 volts. The applied signals will vary the frequency from that established by the panel controls. A positive voltage will increase the frequency, and a negative voltage will decrease the frequency. The response versus voltage is not linear, and the sensitivity and exact response characteristic depend upon the microwave tube used. These characteristics vary somewhat between individual tubes of the same model as well as between plug-in units, so that some experimentation will be required to achieve calibrated results.

The signal source required for this input must be floating and capable of supplying the required helix current to the BWO. This current requirement is given in the instruction manual for the plug-in. Since the helix is operated only a few millivolts below ground, no high voltage insulation is required.

The high frequency response of this helix modulation circuit is in the megacycle range, and is normally limited by the ability of the signal source to drive the circuit input capacitance. This capacitance, due to terminal connections and wiring, etc.,



NOTES:
1. USE SWITCHCRAFT #297 3-CIRCUIT PHONE PLUG.
2. DO NOT EXCEED ± 50 V CONTROL SIGNAL

FIGURE 3-8. REAR PANEL CONNECTIONS FOR REMOTE FREQUENCY STABILIZATION OR HIGH-FREQUENCY FM MODULATION

is about 100 pf. Frequency- and phase-lock response approaches the nanosecond range, and over-all loop stability is again usually limited by the ability of the discriminator or stabilizer used to drive the helix.

Separate procedures are given below for frequency stabilization and for high frequency fm modulation.

3.11.3.1 PROCEDURE FOR REMOTE FREQUENCY STABILIZATION. Proceed as follows:

a. Place the instrument in operation for any single-frequency mode, following the procedure of Paragraph 3-6.

b. Tap off a portion of the rf output signal through a coupler to drive the external discriminator or stabilizing device.

c. Connect the discriminator output through a shielded two-conductor cable to a three-terminal phone plug which mates with the REMOTE FREQUENCY STABILIZING jack, as shown in Figure 3-8. Be sure to observe the proper polarity sense.

d. Adjust the discriminator or stabilizer output as necessary to obtain optimum stabilization.

3.11.3.2 PROCEDURE FOR HIGH-FREQUENCY FM MODULATION. Proceed as follows:

a. For modulation in single-frequency modes, make switch settings as directed in Paragraph 3.11.1.2 a. For modulation in swept-frequency modes, make switch settings as directed in Paragraph 3.11.1.4 a.

b. Connect the modulating signal through a shielded two-conductor cable to a three-terminal phone jack which mates with the REMOTE FREQUENCY STABILIZING jack, as shown in Figure 3-8. Be sure to observe the proper polarity sense.

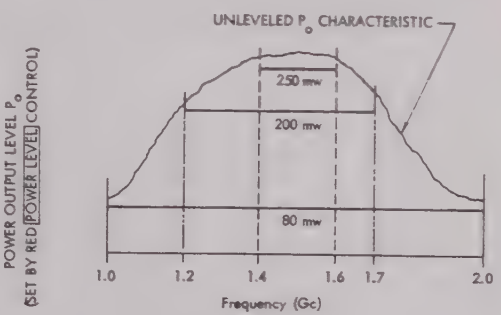
c. Note that the applied modulation must not be allowed to drive the rf output frequency outside the range of the plug-in. The instantaneous frequency output will be the indicated single-frequency dial setting plus the increment due to signal applied to the helix. Separate calculations or empirical checks must be made for each tube if a particular known deviation is required because of sensitivity variations.

3.12 RF OUTPUT LEVELING AND POWER LEVEL ADJUSTMENT.

3.12.1 GENERAL DATA (See Figures 3-9 and 3-10). All Oscillator Plug-in units include a leveler-amplifier to permit rf power output leveling and power level adjustment when used with an appropriate sampler. Plug-in units with K, AK, and CK model number suffixes have an internal rf sampler. These units can be leveled with or without an external rf sampler. Other plug-in units can provide output leveling only if an external sampler is used.

Leveling of the rf power source is useful for many applications because system output variations can then be directly attributed to the equipment under test. The power output characteristic of microwave oscillator tubes (BWO or VTM as used in the Model 650 Series) is not constant through the frequency range of each tube. A typical power output characteristic of an unleveled BWO tube is bell-shaped, with 6 to 8 db higher power at band center, and with some lesser narrow-band variations superimposed across the band. An unleveled VTM typically has a power variation of only 2 or 3 db across the band, dropping at band edges and varying randomly in between. When operating with internal leveling (K, AK, and CK plug-in units), these power variations at the RF OUTPUT connector can be held to within the limits shown in Table 1-2 for each plug-in unit (generally +0.3 db) across the full bandwidth of the plug-in unit. By using the external leveling mode (all plug-in units) with a suitable external sampler located at the load, power variations at a remote load can be kept to within the same limits.

The RF OUTPUT jack of the plug-in units with internal sampling is physically the primary ouput terminal of the internal sampling coupler. Therefore, "at-the-load" leveling performance with internal leveling can be obtained by connecting the load directly to the RF OUTPUT jack. The internal low-pass filter (BWO units) or circulator (VTM units) contained in the plug-in unit



NOTE: THE RED POWER LEVEL CONTROL ADJUSTS THE POWER LEVEL TO A POINT WHERE FULL-BAND LEVELING TAKES PLACE WHEN TURNED TO A MID-RANGE POSITION. TURNED CLOCKWISE FROM THAT POSITION, IT RAISES THE OUTPUT POWER LEVEL FOR NARROW-BAND LEVELING AS ILLUSTRATED ABOVE. TURNED COUNTERCLOCKWISE FROM THAT POSITION, IT REDUCES THE FULL-BAND LEVELED OUTPUT OVER A RANGE OF ABOUT 5 DB ON BWO UNITS, AND ON VTM UNITS WITH SOLID-STATE LEVELING (10 DB ON BWO UNITS WITH C SUFFIX).

FIGURE 3-9. TYPICAL LEVELER PERFORMANCE

adequate isolation with most loads. (This element is etween the microwave tube and the internal sampling nd is thus within the leveled loop for either internal l leveling.) Where the load cannot be connected dir- he RF OUTPUT jack, additional level variations will ed in the signal supplied to the load by the unavoid- atch present in the connecting coaxial or waveguide d other intermediate components. In this case, improv- nance can be obtained with "at-the-load" leveling us- ternal sampler located at the input terminal to the load.

rs, whenever external sampling is used, the sampler located at the load if possible, and otherwise as close d as possible, to minimize VSWR-producing components he leveled loop and the load.

er-amplifier system used in ALFRED plug-in units de- n amplitude-correcting feedback signal by comparing level from the internal or external sampling detector erence signal set by the POWER LEVEL control. A al amplifier automatically adjusts the power level wo signals cancel. In leveled operation, when the EVEL control setting corresponds to a level higher than eled power output over part of the band, the leveler is over only that portion of the band that can be leveled ected value. On units with internal sampling, the sen- the internal detector circuit is set to provide full- n leveling at a mid-range position of the POWER ntrol. This allows the power level to be adjusted to a lue for narrow-band leveling. It also allows at least justment of output power level with full-band leveling units, and an adjustment of up to 1 db with full-band n VTM units. For external leveling, the detector used ble to develop about -100 mv (-60 mv minimum) at the LER INPUT jack with the maximum output power avail- r full-band-leveled conditions. Input impedance of this out 3 K. The RF SAMPLER SENS screwdriver control adjusts sivity of the leveler-amplifier to the external sampler, he detector signal to be balanced against the internal at the desired setting of the red POWER LEVEL control.

l leveling can be provided at a level that is within 1 db nimum-power point of the unleveled output characteris- larly, leveling over any portion of the band can be at a level that is within .5 db of the minimum-power he unleveled output characteristic within that portion nd. Thus, over narrow mid-band ranges where the avail- er is higher than at band edges, higher than rated full- eled power may be obtained, as shown in Figure 3-9. EVELED light goes out only when the output power is ver the frequency range being swept.

external leveling loop for obtaining optimum power r the load is shown in Figure 3-10A. It consists of a al coupler to sample a portion of the rf output, and a ro convert the sampled rf into a dc signal for the mplifier. An external 3 db pad or low-pass filter to ad mismatch from the ascillator tube is not normally with plug-in units having a K Model-number suffix, f the internal isolation provided within the plug-in n external low-pass filter can be used to improve leveling performance with plug-in units not having el-number suffix (which do not contain a low-pass rmally). The external low-pass filter should be con- tween the RF output connector and the sampling nput.

The ALFRED Model 1001 Crystal Detector can be used with power levels up to 100 mw. It requires no more than 1 mw input power to develop -60 mv when driving the 3000-ohm input impedance of the RF SAMPLER INPUT jack. The Model 1001 Detectors have exceptionally uniform, matched characteristics. They provide square-law performance within 0.5 db from low level up to 1 mw, and have a sensitivity of greater than 0.5 mv/μw at low levels. These features are advantageous where the leveler sampler circuit is to be matched with the reflected power sampler circuit in reflectometer measurements, as discussed in Paragraph 3.17.3. When the Model 3000, 7051 Network Analyzer is to be used for readout/display, the Model 1403 Crystal Detector Set, consisting of three selected, matched Model 1001 Detectors, is available. In every setup, a sampler should be chosen which provides at least 1 mw into the detector arm at the output level to be used. An alternate method of external leveling which provides an additional power level adjustment range up to 50 db is shown in Figure 3-10B. This method uses the ALFRED Models 1151-1153 Sampler Attenuators which consist of an ALFRED RF Sampler followed by a precision variable attenuator. The variable attenuator is actually a variable directional coupler and its frequency response is very carefully matched with that of the sampler, so that exceptionally flat output over a wide frequency and attenuation range is obtained. Power variation across the band at any level with a 20-db range can be held to within ± 0.5 db with this arrangement.

In units with PIN diode leveling (650A, AK, C, and CK Series Plug-in units), the output leveling is provided by solid-state attenuation in the output circuit while the oscillator tube continues to operate at full power. Thus, level correction is made independently of the tube and excellent frequency stability is maintained. In other units which have grid-leveled BWOs, some frequency pulling will take place during leveling. This is an inherent characteristic of BWO tubes. Injector-leveled VTMs exhibit a similar characteristic.

The rf output level can be adjusted in all units when operating in the leveled mode, and in all units with waveguide output and, or with A, AK, C, and CK model number suffixes when operating in the unleveled mode.

The procedures for each type of leveling and power level adjustment are given separately below.

3.12.2 LEVELING WITH INTERNAL SAMPLING (650K, AK AND CK SERIES PLUG-IN UNITS ONLY). Proceed as follows:

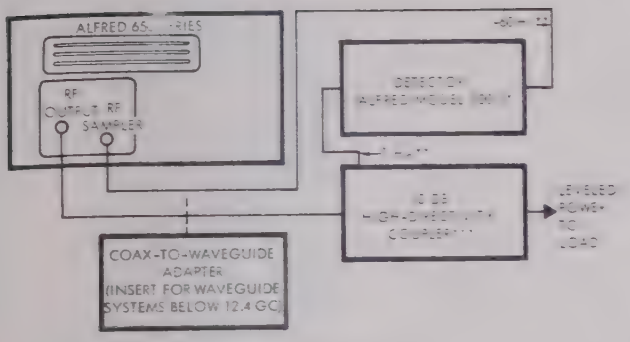
a. Set all controls (except those on the plug-in panel) as directed in the preceeding paragraphs, to obtain the desired operating conditions.

b. Make the following control settings on the plug-in panel:

RF OUTPUT Selector switch to LEVELED.
RF SAMPLER Snap switch to INT.

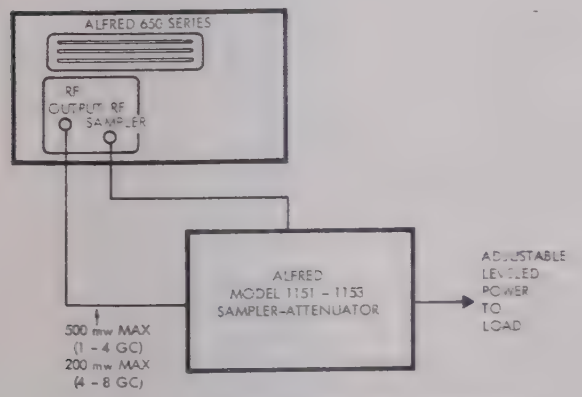
c. The red POWER LEVEL Control will reduce the leveled output power to the value required for full-band leveling on all units, and then an additional 5 db on most units* when turned from its fully clockwise position to its fully counterclockwise position (see Figure 3-9). Set this control to the desired level. The UNLEVELED light will go off when the output is leveled over the frequency band being swept. On grid-leveled VTM units, distortion may occur with reduction below the full-band leveling point. On grid-leveled BWO units, do not attempt to reduce leveled power more than 5 db below the minimum unleveled output power. On solid-state leveled units, the full

*10 db on units having C suffix.



*ABOVE 12.4 GC, USE A SUITABLE ALTERNATE DETECTOR.
**MINIMUM REQUIRED FOR LEVELING AT MAXIMUM FULL-BAND LEVELED POWER.
***10-DB COUPLER SHOWN APPLIES TO PLUG-IN UNITS WITH MAXIMUM FULL-BAND LEVELED POWER OF 20 MW. USE LOWER COUPLING VALUE AND/OR INSERT A FLAT PAD BETWEEN THE COUPLER AND DETECTOR FOR PLUG-IN UNITS WITH HIGHER LEVELED OUTPUT POWER. LOCATE THIS COUPLER AS CLOSE AS POSSIBLE TO THE LOAD FOR BEST LEVELING PERFORMANCE.

A. External Leveling with Individual Components



B. Leveling with ALFRED Model 1151 - 1153 Sampler-Attenuator Located at the Load (1 - 8 Gc Coverage)

FIGURE 3-10. TYPICAL CONNECTIONS FOR EXTERNAL LEVELING

available control range may be safely used.

d. For remote control of output level, turn the red POWER LEVEL control fully clockwise and connect a level-programming network to the REMOTE POWER LEVEL banana jacks on the rear panel as shown in Figure 3-3.

3.12.3 LEVELING WITH EXTERNAL SAMPLING (ALL PLUG-IN UNITS). Proceed as follows (See Figure 3-10):

a. Connect to the RF OUTPUT line a suitable sampling coupler and detector to develop an output of -100 mv (-60 mv, minimum) corresponding to the minimum-output point in the spectrum. Connect the output of the sampler detector to the RF SAMPLER INPUT jack, which has an input impedance of approximately 3 K ohms. The ALFRED Models 1151 to 1153 Sampler-Attenuators combine a sampling coupler, detector, and attenuator in one convenient package. The ALFRED Model 1001 Crystal Detector is also available for use with standard couplers. Use high-directivity couplers to minimize leveling error due to reflected power from high-VSWR loads.

b. Set all controls (except those on the plug-in panel) as directed in the preceeding paragraphs, to obtain the desired operating conditions.

c. Make the following control settings on the plug-in panel:

RF OUTPUT Selector switch to LEVELED.
RF SAMPLER Snap switch (if present) to EXT.

d. Observe the output leveling performance across the band, by temporarily connecting the termination (or a second coupler) on the RF OUTPUT line to a power meter or oscilloscope, through a suitable detector such as the ALFRED Model 1001. Sweep across the frequency range of interest and check whether the output is leveled. Full-band leveled performance should be obtained with the red POWER LEVEL control turned to a mid-range position. This will allow higher narrow-band leveling and also provide an additional 5 db* reduction range when the control is turned fully counter-clockwise, as shown in Figure 3-9. If necessary, adjust the RF SAMPLER SENS. panel screwdriver control to provide the proper response for the detector used, to permit full-band leveling at an appropriate position of the POWER LEVEL control. The UNLEVELED light will go off only when power is leveled over the band being swept. Turning the RF SAMPLER SENS control clockwise reduces the sensitivity of the leveler amplifier to the external sampler signal and thereby raises the power level obtained for any setting of the POWER LEVEL control. This has the effect of moving the full-band leveling position of the POWER LEVEL control toward its counterclockwise limit. Turning the RF SAMPLER SENS. control counter-clockwise increases the sensitivity of the leveler-amplifier to the external sampler signal, and thereby reduces the power level obtained for any setting of the POWER LEVEL control. This has the effect of moving the full-band leveling position of the POWER LEVEL control toward its clockwise limit. If the desired leveling response cannot be obtained with any setting of the RF SAMPLER SENS. control, check whether insufficient power is reaching the external sampler detect through the sampling coupler used.

*10 db on units having C suffix.

CAUTION

Adjust the RF SAMPLER SENS control with a screwdriver made of plastic or other non-ferrous material, to avoid damage to the microwave tube.

e. Follow Steps c., d., and e. of Paragraph 3.12.2 above. On waveguide output units, to obtain optimum leveled performance, the black POWER LEVEL control should initially be turned fully clockwise for maximum power output. Set the desired power level using the red POWER LEVEL control. Then for optimum performance, turn the black POWER LEVEL control counterclockwise until the UNLEVELED light comes on, and back off clockwise until the light goes off again. This provides the desired output level while allowing the tube to operate at maximum leveled power, through use of the flap attenuator. If more power level reduction than that provided by the red POWER LEVEL control is required, the black POWER LEVEL control can be used to obtain it. Note that when the black POWER LEVEL control is used to provide reduction of output level, it will reduce the output of the external leveler sampler since it is now within the rf feedback loop. Therefore, it may be necessary to adjust the RF SAMPLER SENS control to restore the desired leveled condition if the black POWER LEVEL control is adjusted.

3.12.4 EXTERNAL POWER LEVEL CONTROL AND PROGRAMING. During leveled operation with internal or external sampling, the rf power output level can be controlled over at least a 5 db* range below the full-band leveling point on most units by use of a 1 K potentiometer or adjustable resistor network connected to the REMOTE POWER LEVEL banana jacks on the rear panel.

The arrangement is shown in Figure 3-3. If the front panel red POWER LEVEL control is turned fully clockwise, the connection to the REMOTE POWER LEVEL jacks will provide output reduction to the full-band leveling point and then at least 5 db* additional reduction, as the wiper of a 1 K potentiometer is moved between the MAX and MIN end taps. If the front panel red POWER LEVEL control is turned away from its fully clockwise position, the total control range of the connection to the REMOTE POWER LEVEL jacks will be reduced, since the two circuits are connected in parallel to generate the internal leveling reference signal.

If desired, the output can be reduced to the level where full-band leveling occurs by means of the front panel POWER LEVEL control, and then the REMOTE POWER LEVEL jacks can be used to provide a control range of about 5 db* below the full-band leveling point. This arrangement eliminates the need for achieving full-band leveling with the remote connection.

A typical response curve for remote power level control is shown in Figure 3-3. Some units with solid-state leveling provide a control range of more than 5 db* below the full-band leveling point, as illustrated. On these units, the full available range may be safely used. On grid-leveled VTM units, distortion may occur with reduction below the full-band leveling point. On grid-leveled BWO units, do not attempt to reduce leveled power more than 5 db below the minimum unleveled output power.

To use external power level control, follow the leveling procedure given above in Paragraph 3.12.2 or 3.12.3, and adjust the power level in accordance with this Paragraph and Figure 3-3.

*10 db on units having C suffix.

3.12.5 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (650A, AK, C, and CK PLUG-IN SERIES ONLY). During unleveled operation, the PIN diode leveler attenuator in the rf output circuit is still operative and may be used to adjust the output level. With the RF OUTPUT Selector switch in the UNLEVELED position, the output level may be reduced by at least 5 db* from the instantaneous unleveled value by turning the red POWER LEVEL control counterclockwise. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects. On these plug-in units, this control must be left in the fully clockwise position to obtain maximum unleveled power.

3.12.6 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (650 and 650K PLUG-IN SERIES ABOVE 12.4 GC ONLY). During unleveled operation, the flap attenuator in the rf output circuit may be used to adjust the output level. This attenuator is operated by the black POWER LEVEL control knob and will reduce the output level by at least 10 db from the instantaneous unleveled value when turned counterclockwise. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects. On these plug-in units, this control must be left in the fully clockwise position to obtain maximum unleveled power.

3.13 USE OF MARKERS

3.13.1 INTERNAL RF MARKERS. The internal rf markers can be used only when the rf output is leveled, and appear in the output as an absorptive dip in the output level. This decrease occurs when the output frequency crosses the setting of the M_1, M_2, and F_0 dial indicators in $F_1 \rightarrow F_2$ and manual sweep modes. In $F_0 \pm \Delta F$ sweep mode, only the M_1 and M_2 markers are operative. The amplitude of the marker dip is variable by the MARKER AMPLITUDE control, increasing as it is turned clockwise out of the OFF position. At the maximum setting, just before the switched EXT position, the amplitude is at least 2 db at the three slower sweep speed ranges, and at least 0.2 db in the fastest sweep speed range. The base width of the markers at maximum amplitude is approximately 0.05% of the full frequency range at all sweep speeds. The base width decreases as the amplitude is decreased. The markers do not appear during retrace if the rf is left on. These markers pips will be found to be even sharper than those obtained with a cavity wavemeter

3.13.2 EXTERNAL VIDEO MARKERS. The external rf markers are provided for use when the rf output is unleveled, and can be used in the leveled condition as well. These markers are provided to the MARKER OUTPUT jack only when the MARKER AMPLITUDE control is in the EXT switched position. They have an amplitude of about -1 V and a width of about 5 μs. Pulse width is independent of the sweep-time used. They can be applied to an oscilloscope display of the detected rf output by summing the signal from the MARKER OUTPUT jack with the detector output at the input to the oscilloscope vertical amplifier, using a BNC tee. It may be necessary to add impedance to either the detector output or video marker lines to match signal levels to obtain the desired presentation. These video markers are not provided during retrace.

The external video markers will be found useful for the following situations:

a. When output is unleveled and rf markers are not available.

b. In reflectometer applications where it is necessary to have a constant drive level to avoid spurious reflections.

c. In measurement applications where level variations in the response swamp out the low-amplitude rf markers.

d. In loss measurements of filters and attenuators where the rf markers are attenuated.

e. In test system applications where it is convenient to have a trigger pulse available when a certain frequency or frequencies are crossed to actuate programmed readout measurements, level changes, etc.

*10 db on units having C suffix.

3.14 RF OUTPUT BLANKING DURING SWEEP RETRACE.

During the sweep modes of operation, the rf power can either be on or off during sweep retrace and until the next sweep is triggered. Selection of either of these conditions is provided by the RETRACE switch. In the OFF position, the rf power is turned off during retrace by biasing the microwave tube beyond beam cut-off. Thus, no rf power appears at the RF OUTPUT connector during retrace. This permits zero reference points to be established.

3.15 AUXILIARY OUTPUT SIGNALS.

For convenience in operating the Model 650 Series with oscilloscope and recorder displays, several auxiliary output signals are supplied. These are discussed individually in the paragraphs below.

3.15.1 OUTPUT SWEEP SIGNAL. This signal is convenient for driving the oscilloscope horizontal channel or the recorder X-axis for display of swept presentations. This signal is available at the front panel OUTPUT SWEEP jack. A fixed +15 V is available from the jack for calibrating the display when the adjacent CALIB button is pressed. The OUTPUT SWEEP signal provided in each mode of operation is tabulated below. The output impedance is 10 K.

Mode:	OUTPUT SWEEP Signal:
Swept $F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$	0 to +15 V linear sawtooth regardless of swept frequency band; 0 V at sweep start and +15 V at sweep stop.
Manual Sweep	0 to +15 V level, proportional to output frequency between F_1 and F_2; 0 V at F_1 and +15 V at F_2.
Single-Frequency, M_0, F_0, M_2	Dc level between 0 and +15 V, proportional to the position of the output frequency within the linear dial range.
Single-Frequency, F_2	Same as manual sweep; +15V when MANUAL SWEEP control is switched to F_2.
Single-Frequency, F_1	Grounded (can be used as zero-set reference).
FREQUENCY Mode Selector OFF	Dc level between 0 and +15 V, proportional to the setting of the F_0 indicator within the linear dial range.

3.15.2 OUTPUT BLANKING SIGNAL. This signal is convenient for driving the oscilloscope Z-axis to blank the presentation trace during sweep retrace. This signal is provided at the front panel OUTPUT BLANKING jack. It has a level of +50 V during retrace and until the next sweep is triggered, and is at 0 V during the sweep. The +50 V output is also supplied continuously during manual sweep, in all single-frequency modes, and when the rf output is turned OFF with the FREQUENCY Mode Selector switch. Output impedance is approximately 10 K ohms.

3.15.3 BLANKING (PEN LIFT) RELAY CONTACTS. A set of form C relay contacts is brought out to the rear BLANKING

CONTACT OUTPUT banana jacks on the rear panel
ner jack is common, and the normally-open (N. O.)
rmally-closed (N. C.) contact jacks are labeled. This
energized whenever the +30 V OUTPUT BLANKING
L is supplied (see above) if the switch above the
ING RELAY CONTACT OUTPUT jacks is in the ON
n. When this switch is in the OFF position, the relay
er be energized. Thus, if the jacks are connected to
scorder pen or blank a scope trace during retrace, the
t switch can be turned OFF to disable the blanking or
when switching temporarily to single-frequency or man-
ep operation. Because of physical response limitations
elay, it does not operate on the two fastest sweep ranges.

REMOTE CONTROL AND PROGRAMMING.

mit incorporation of the Model 650 Series into auto-
programmed test systems, all major functions that cannot
ectronically preset with the panel controls are remotely
mmable. These functions are tabulated below, with ref-
to a previous paragraph for details.

uency Programming: Any desired sweep start frequency,
sweep bandwidth can be programmed and controlled
motely. For control with voltages in the 0 to +15 V
e, see Paragraph 3.11.1. For control with passive resist-
networks, see Paragraph 3.11.2.

plitude Programming: Any desired amplitude level from
on to full-off can be programmed and controlled exter-
For full-range control with voltages in the 0 to −10 V
e, see Paragraph 3.10.2. For control within a 5 db range
passive resistance networks in leveled operation, see
graph 3.10.3.

er Level Programming: With internal leveling or external
ing, with a fixed-response sampler, the power level can
motely programmed and controlled within a 5 db range
passive resistance networks. With an external sampler-
nductor, the control range can be increased. See Para-
h 3.12.

ep Recurrence Programming: Sweeps can be externally
ered at any desired recurrence rate, with a 2 V signal.
Paragraph 3.8.

APPLICATIONS INFORMATION.

GENERAL. The following paragraphs indicate typical
ups which are useful for basic swept-frequency test
ons of the Model 650 Series. Included are procedures
surement of the most commonly tested microwave param-
cluding reflection coefficient, VSWR, and transmission
ss. Most of these set-ups can be used for single-fre-
testing as well.

READOUT DISPLAY TECHNIQUES.

OSCILLOSCOPE READOUT DISPLAY. The fastest
eeds provided by the Model 650 are ideal for flicker-
graphic display for visual inspection and for moving
ent records with an oscilloscope camera. A suitable
nding detector, such as the ALFRED Model 100T, must
the properly drive the oscilloscope. The continuous, real
play of a broad swept-frequency range on the oscillo-
CRT permits instantaneous "quick-look" evaluation of
rance throughout the band of interest. It also allows
e monitoring of the effects of adjustments on the device
er.

A wide variety of oscilloscopes can be used for swept-frequency performance measurements. A low-frequency oscilloscope having a vertical bandwidth of 300 kc or more and dc-coupled vertical and horizontal input channels is adequate. Depending on test power levels and detector characteristics, it may be necessary to use an oscilloscope with high-gain vertical sensitivity. The ALFRED Model 100T Crystal Detector provides more than 0.5 millivolts per microwatt at low levels, with square-law performance accurate to ± 0.5 db, thus providing an output of 5 millivolts at -20 dbm. The ALFRED RF Samplers (see Table 3-4) offer similar response over their individual frequency ranges. An oscilloscope vertical sensitivity of 1 mv/cm will thus be satisfactory for many applications, but for low-VSWR reflection coefficient measurements and operation with less sensitive detectors, it will be useful to have an oscilloscope with vertical sensitivity of 100 μv/cm.

While the horizontal sweep of the oscilloscope and the frequency sweep of the Model 650 can be individually synchronized to the line or to some external timing signal, it will usually be preferable to use the Model 650 OUTPUT SWEEP signal to drive the horizontal deflection channel of the oscilloscope. This 0 to +15 V sweep signal provides an accurate frequency axis for the sweep display. If the Model 650 RETRACE switch is placed in the OFF position, the oscilloscope display will automatically retrace on the zero reference line, providing a continuous zero-power reference trace in recurrent-sweep modes. When the RF is left on during retrace, or when the −3C ∧ BLANKING OUTPUT signal is used to blank the CRT during retrace, it will be convenient to set the zero-power position of the trace to coincide with a graticule line for reference.

For certain applications, it is possible to pre-calibrate the oscilloscope CRT face with a transparent overlay or mask markings so that the familiar "grease pencil" reference calibration traces need not be made. This technique is covered in detail below. It takes advantage of the fact that if the "full power" and "no power" traces are adjusted to a pre-selected deflection, intermediate response in a flat system will appear at vertical intercepts which can be calculated and labeled in advance. This provides pre-calibration for loss and reflection coefficient measurements. It can be extended to gain measurements by coordinating the calibration markings with vertical amplifier attenuator settings. For accuracy, this technique requires use of external leveling with the sampling coupler located at the load: test power levels that allow the output response of the crystal detector to operate in its square law range; and maximally flat couplers and attenuators across the leveled band.

In other applications, where power is unleveled or where components are not flat, the test system can be calibrated in the conventional way, by using an accurate variable attenuator to duplicate the loss or offset the gain of the device under test.

3.17.2.2 RECORDER READOUT DISPLAY. The slower sweep speeds provided by the Model 650 are ideal for driving X-Y recorders to make a permanent graphic record of swept-frequency test performance. Virtually any recorder with sensitivity of 2.5 mv/in. will be satisfactory for most applications, when the ALFRED Model 100T Crystal Detector is used. For low-VSWR reflection coefficient measurements and operation with less sensitive detectors, it will be useful to have a recorder with 0.1 mv/in. sensitivity. The graph limits should be set up by adjusting the recorder controls with the pen lifted. Then a single, manually triggered sweep can be used to obtain the test record.

The Model 650 OUTPUT SWEEP signal is ideal for driving the X-axis of the recorder. This 0 to +15 V sweep signal provides an accurate frequency axis for the swept display. If the Model 650 RETRACE switch is placed in the OFF position, the graph will automatically retrace on the zero reference line. If the rf is left on during retrace, the BLANKING RELAY CONTACT output terminals on the rear of the Model 650 can be used to lift the recorder pen automatically during retrace on either of the two slowest sweep ranges. For faithful reproduction of discontinuities in the test response, one of the manual sweep modes may be used to drive the recorder slowly through the point of interest. Manual sweep is also useful for operating recorders without automatic pen controls.

3.17.2.3 METER READOUT DISPLAY. The 100-second sweep speed, selected by turning the SWEEP TIME VERNIER control fully counterclockwise in the 10-second SWEEP TIME Selector switch position, can be used for driving displays in which the readout device is a meter. This sweep speed provides responses within the response capabilities of most meters. Swept-frequency measurements of reflection coefficient, VSWR, noise figure, and power levels can thus be made with direct-reading meters. The internal 1000-cps square-wave modulation can be used with meters which require audio modulation of the rf signal, including most VSWR and ratio meters. Manual sweep can be used to investigate points of rapid variation.

3.17.3 REFLECTOMETER TECHNIQUES FOR VSWR MEASUREMENT WITH FLAT, PRE-CALIBRATED DISPLAY. (See Figure 3-11.)

3.17.3.1 GENERAL DATA. Reflectometer test systems measure the reflection coefficient of a load by separating the reflected wave propagated in the source-to-load line from the incident power. If the incident power is leveled at the load by use of an external sampling coupler located at the load, the incident power will remain constant over the test band. A single directional coupler can then be used to measure the reflected power variations due to load mismatch.

A typical set-up is shown in Figure 3-11. An attenuator pad can be used at the output of the Model 650, if necessary to reduce the level to the values shown. The 10-db couplers or samplers used for sampling incident power for the leveler and for sampling reflected power for readout should be matched as closely as possible (and preferably should be maximally flat). The test arrangement shown in Figure 3-11 will compensate for non-flat performance of the couplers if they are matched. This is because the leveling in accordance with the curve of the first coupler will then produce a power level across the band that provides constant output from the second coupler.

To test waveguide systems below 12.4 Gc, place a coax-to-waveguide adapter at the output of the Model 650 and at the input to the detectors, unless waveguide crystal detector mounts are used. This permits use of more accurate high-directivity waveguide directional couplers. Attenuator pads, filters, and adapters placed between the Model 650 RF OUTPUT connector and the external leveling sampler will not degrade the leveling performance, provided sufficient power is supplied to the leveler detector to generate a drive of -100 mv at the point of minimum unleveled output. The level must be kept within the square-law range of the reflected power detector. If a pre-calibrated display is to be used without individual calibration using a variable attenuator, the level must be kept within the square-law range of both detectors if automatic compensation for non-flat couplers is to be obtained. Otherwise, i. e. with flat couplers the power level applied to the leveler sampler detector can exceed the square-law range.

The reflectometer technique theoretically has excellent accuracy over a wide VSWR range. The accuracy of a VSWR measurement of 1.22 is typically ± 0.05. The lowest VSWR that can be accurately measured is limited by the directivity of the reflected power readout coupler. Low-directivity couplers permit combination of a small amount of incident power with the reflection readout line. This can be enough to produce inaccuracy when the reflection level is low. Thus, measurement of low VSWR ratios requires high-directivity couplers. For reflectometer measurements of a VSWR as low as 1.10, coupler directivity should be 30 db or greater; for a VSWR of 1.05, coupler directivity should be 35 db; for a VSWR of 1.03, coupler directivity should be 40 db. The measurement of large VSWR ratios is limited by the directivity of the incident power sampling coupler.

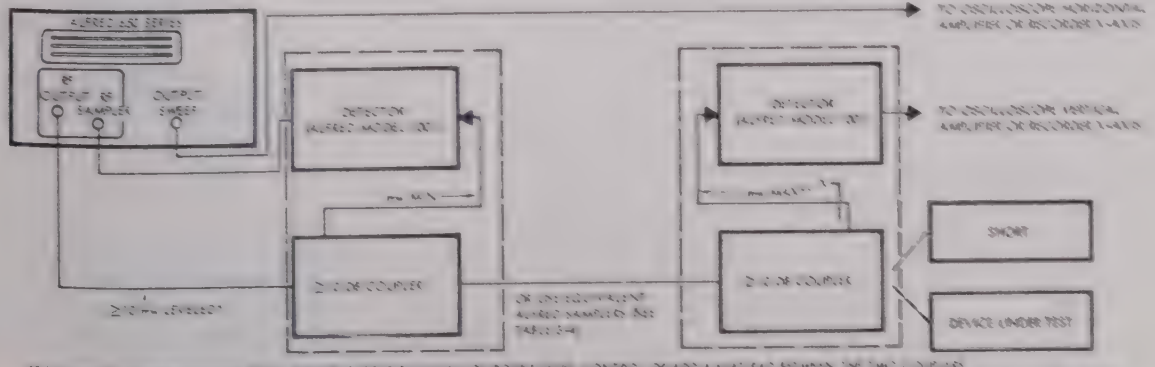
The procedure given below provides for measurements which are calibrated to a direct-reading tick-mark scale located at any convenient point on the CRT graticule or recorder graph paper. Flat, leveled performance across the band eliminates the need for recording full-width calibration traces.

3.17.3.2 DETAILED PROCEDURE. To calibrate the oscilloscope or recorder and carry out VSWR measurements, set up equipment as shown in Figure 3-11 and proceed as follows:

a. Adjust the Model 650 controls to establish the desired sweep mode and external leveling.

b. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

c. Adjust the oscilloscope or recorder horizontal gain control


TO OSCILLOSCOPE HORIZONTAL AMPLIFIER OR RECORDER X-AXIS
RF OUTPUT 50Ω SAMPLER
OUTPUT SWEEP
DETECTOR (ALFRED MODEL 100)
TO OSCILLOSCOPE VERTICAL AMPLIFIER OR RECORDER Y-AXIS
SHORT
DEVICE UNDER TEST

*FOR DEVICES REQUIRING LOWER LEVEL, REDUCE OUTPUT BY MEANS OF POWER LEVEL CONTROL OR ADD A VARIABLE BETWEEN THE TWO COUPLERS
**DO NOT EXCEED THE SQUARE-LAW RANGE OF THE DETECTOR (SIGNAL AMPLITUDE ACROSS THE OSCILLOSCOPE VERTICAL DEFLECTION PLATES MUST BE WITHIN THE SQUARE-LAW PERFORMANCE RANGE OF THE DETECTOR)
+ 0.5 DB UP TO ABOUT 1 mm.) ABOVE 12.4 GC USE A SUITABLE ALTERNATE DETECTOR OR SAMPLER
X - FOR CALIBRATION OF INDIVIDUAL TEST SET-UPS, INSERT A PRECISION VARIABLE ATTENUATOR AT POINT X.

FIGURE 3-11. REFLECTION COEFFICIENT (VSWR) MEASUREMENTS USING CALIBRATED OSCILLOSCOPE OR RECORDER

tain the desired calibration in Gc per cm or Gc per from the Model 650 OUTPUT SWEEP drive signal.

st the oscilloscope vertical offset controls to place trace on the lowest horizontal line of the graticule (5 cm center on a standard 6-cm scope). Adjust the recorder position as necessary to place the pen over the bottom on the graph. This line corresponds to zero reflection ero return loss), which can be calibrated as 1.00 on a ct-reading VSWR scale on the CRT face or recorder paper.

TE: Detector output connections should be made with er polarity to provide up-scale deflection on the lloscope or recorder.

e a 100% short on the output end of the readout coupler.

t the MODULATION Selector switch to AM OFF and k for leveled output by observing that the UNLEVELED t is not lit. Adjust the oscilloscope or recorder vertical nplifier and calibration vernier controls as required to e the trace on the top line of the graticule or graph er. Do not readjust the zero position controls. If the ected output level is above the square-law range of the ector used, reduce the Model 650 output power with the WER LEVEL control. The line now being traced represents % reflection or 0 db return loss, which can be calibrated on a direct-reading VSWR scale on the CRT face or order chart paper.

ove the reflectometer short installed in Step e. above observe the display with the output open-circuited. proximately the same deflection should be obtained, since open circuit discontinuity reflects most of the power a minimum of transmission. If the deviation from full-e deflection is within ± 10%, adjust the vertical ampli-vernier control halfway between the settings that place "short" and "open" ∞ VSWR reference line on the de-scale division. If substantial difference exists between e two calibration lines, investigate the source of error the measurement system, which may be a low-directivity pler.

direct-reading VSWR scale may now be calibrated for full range of VSWR from 1 to ∞ by using a slide rule, a or scale calibrated in divisions of the unit spacing on CRT graticule or recorder graph paper, and the follow-equations:

Reflection coefficient equation:

$$\rho = \frac{E \text{ reflected}}{E \text{ incident}} = \frac{VSWR - 1}{VSWR + 1}$$

$$= \sqrt{\frac{P \text{ reflected}}{P \text{ incident}}} \text{ as measured with voltage signals from a square-law detector.}$$

VSWR equation:

$$VSWR = \frac{1 + \rho}{1 - \rho}$$

where VSWR = ratio of the maximum to minimum voltage in the standing wave along the transmission line;
ρ = magnitude of the reflection coefficient;
$-20 \log \rho$ = definition of return loss.

mple A

Calibrate the vertical center point of the 1.00-to-∞ VSWR display.

At the center point, the detector output signal is 1/2 that at full reflection. Since the trace made with full reflection corresponds to the incident power level, the reflected signal which gives a center-scale deflection has 1/2 the power of the incident wave because square-law detector readings are directly proportional to power. From equation (1) above,

$$\sqrt{.5} = \rho = 0.707$$

from equation (2),

$$VSWR = \frac{1.707}{.293} = 5.83$$

Example B

Similarly, for a 6-unit scale such as a standard 6-cm CRT graticule, the divisional calibration points between 1.00 and ∞ can be calculated as 2.38, 3.73, 5.83, 9.9 and 22.

If the VSWR is below 2.0, it will be convenient to increase the vertical amplification of the oscilloscope or recorder by a factor of 10 or more, to increase the sensitivity of the direct-reading display. The scale must then be re-calibrated since the ∞ VSWR line which represents incident power is effectively moved off-scale by an amount equal to the full-scale deflection times the change in amplification. The 1.00 VSWR line remains unchanged and the display is effectively expanded.

Example A

Calculate the new VSWR values to calibrate the half-scale and full-scale VSWR lines when input amplification is increased by 10:1.

At full scale deflection, since the ∞ VSWR line (which represents incident power) has been moved a distance of 10 scale amplitudes above the scale, the reflected wave has 1/10 the power of the incident wave. From equation (1),

$$\rho = \sqrt{\frac{1}{10}} = .316$$

from equation (2)

$$VSWR = \frac{1 + \rho}{1 - \rho} = \text{[illegible]}$$

Similarly, at half scale, the reflected wave has 1/20 the power of the incident wave and

$$\rho = \sqrt{\frac{1}{20}} = .224$$

$$VSWR = 1.58$$

Example B

Similarly, for 10:1, 20:1, 30:1, and 100:1 amplification increases, the scale divisions for a 6-unit scale will be calculated below:

Amplification	1	2	5	10
VSWR	1.00	1.00	1.00	1.00
	1.22	1.10	1.04	1.02
	1.58	1.30	1.08	1.04
	2.38	1.86	1.22	1.09
	3.73	2.73	1.58	1.22
	6.0	4.5	2.38	1.58
	9.9	7.5	3.73	2.38
	22	16.8	8.0	4.5

j. Connect the device under test to the output end of the readout coupler. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, switch to the vertical channel amplification step that brings the trace closest to full-scale deflection. Then select the precalibrated scale corresponding to the amplification setting used and read the VSWR directly from the display.

k. Obtain recorder plots or oscilloscope photos for permanent record as desired.

l. Repeat Steps j. and k. for all devices to be tested.

3.17.4 REFLECTOMETER TECHNIQUES FOR VSWR MEASUREMENT WITHOUT FLAT DISPLAY. (See Figure 3-11.)

3.17.4.1 GENERAL DATA. In some test situations, it will not be possible to use the flat, tick-mark-calibrated readout display method outlined above. These situations include set-ups where the reflected power detector must be operated above square-law level, where a non-flat pad must be used to reduce the power level outside the leveled loop, where the leveler sampling coupler cannot be located next to the reflectometer output coupler for true incident power leveling, or where internal leveling is used.

In such cases, a variable precision attenuator can be inserted into the system between the reflectometer output coupler and the reflected power detector to calibrate the system. Usually, calibration lines the full width of the display will be required to calibrate the display because of level variations across the band. These can be traced in grease-pencil on a CRT graticule overlay, or recorded in a contrasting color on the X-Y recorder graph.

For this test method, use the test set-up shown in Figure 3-11 except that external leveling is optional, and the attenuator must be added at point X. Refer to the text discussion in Paragraph 3.17.3.1 for additional data on the reflectometer instrumentation technique. Follow the procedure given below.

3.17.4.2 DETAILED PROCEDURE. To calibrate the oscilloscope or recorder and carry out VSWR measurements, proceed as follows:

a. Follow Steps a. through e. of 3.17.3.2 with changes as required by the differences in test set-up used.

b. Turn the precision variable attenuator at point X to 0 db.

c. Turn the MODULATION Selector switch to AM OFF and check for leveled output by observing that the UNLEVELED light is not lit.

d. To make an individual measurement, connect the device under test to the output end of the readout coupler. Adjust the oscilloscope or recorder controls to obtain a performance trace at near-full-scale deflection. Note this trace on the display. Then, without adjusting the display controls, substitute the 100% short and adjust the precision variable attenuator to produce a calibration trace which intersects the performance trace. Several settings of the precision variable attenuator may be required to calibrate the performance trace at different points of intersection, depending upon the variation of VSWR over the band tested. The db readings obtained from the precision variable attenuator can be read directly as "return loss," which equals $-20 \log_{10} \rho$. These readings can thus be converted to ρ and then to VSWR.

Example A

The precision attenuator reading at one point of intersection between the performance and calibration traces is 26 db. Calculate the VSWR:

From equation (2) under Step h. of 3.17.3.2 above,

$$26 = 20 \log_{10} \rho$$

$$\log_{10} \rho = \frac{-26}{20} = -1.3$$

$$\rho = 10^{-1.3} = 0.05$$

$$\text{VSWR} = \frac{1.05}{.95} = 1.1$$

Example B

Other values can be calculated as above or found in standard microwave reference handbooks.

e. To calibrate the display for a series of measurements using the precision variable attenuator, several calibration traces as above can be made for various attenuator settings with the reflectometer output shorted. If a different setting of the recorder or oscilloscope input amplifier is required to bring the trace into position when a device is tested, the db equivalent of that amplification change must be added to the "return loss" value in computing equivalent VSWR. If the crystal is operating in its square-law range, the db equivalent of the amplification change is 10 times the $\log_{10}$ of the voltage amplification added. For optimum results, and particularly if there is any doubt as to crystal performance, run calibration traces at the same amplification setting that gives on-scale readout with the device under test.

f. Obtain recorder plots or oscilloscope photos for permanent record as desired.

g. Repeat Steps d. or e. and f. for all devices to be tested.

3.17.5 BASIC TECHNIQUE FOR MEASUREMENT OF GAIN AND LOSS. (See Figure 3-12.)

3.17.5.1 GENERAL DATA. The basic test set-up for measurement of gain and loss can be used for gain vs. frequency measurements, loss vs. frequency measurements, dynamic range measurements, stability measurements, or for measurements of a controlled gain or loss parameter vs. the control parameter. A typical set-up, which can be modified to suit an individual situation, is shown in Figure 3-12.

The precision variable attenuator permits exact calibration of the gain or loss performance in db, and allows reduction of the input level to the equipment under test, if required by its sensitivity range. The pad attenuator at the output of the equipment under test minimizes output reflections.

For loss measurements where the output level obtained from the equipment under test is much below -20 dbm, it is often advantageous to use a low-noise TWT amplifier, such as an instrument of the ALFRED 5000 Series, to raise the level to the sensitivity range of standard detectors. For gain measurements, to avoid exceeding the maximum power dissipation of the detector, the precision variable attenuator can be used to reduce the input signal level at the equipment under test, or a larger attenuator can be connected to the equipment output. Use the technique which best suits the sensitivity and performance ranges of the equipment under test. The detected output can be applied

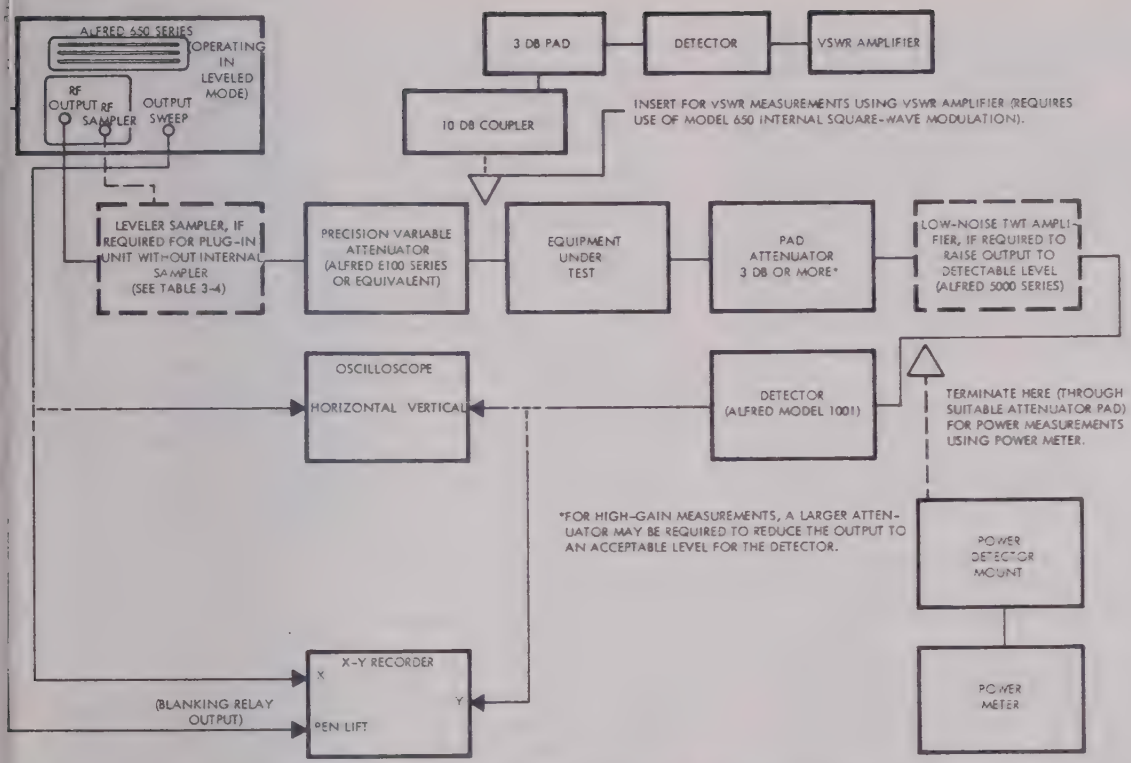

ALFRED 650 SERIES
OPERATING IN LEVELED MODE)
RF OUTPUT
RF SAMPLER
OUTPUT SWEEP
3 DB PAD
DETECTOR
VSWR AMPLIFIER
10 DB COUPLER
INSERT FOR VSWR MEASUREMENTS USING VSWR AMPLIFIER (REQUIRES USE OF MODEL 650 INTERNAL SQUARE-WAVE MODULATION).
LEVELER SAMPLER, IF REQUIRED FOR PLUG-IN UNIT WITHOUT INTERNAL SAMPLER (SEE TABLE 3-4)
PRECISION VARIABLE ATTENUATOR (ALFRED E100 SERIES OR EQUIVALENT)
EQUIPMENT UNDER TEST
PAD ATTENUATOR 3 DB OR MORE*
LOW-NOISE TWT AMPLIFIER, IF REQUIRED TO RAISE OUTPUT TO DETECTABLE LEVEL (ALFRED 5000 SERIES)
OSCILLOSCOPE
HORIZONTAL VERTICAL
DETECTOR (ALFRED MODEL 1001)
TERMINATE HERE (THROUGH SUITABLE ATTENUATOR PAD) FOR POWER MEASUREMENTS USING POWER METER.
*FOR HIGH-GAIN MEASUREMENTS, A LARGER ATTENUATOR MAY BE REQUIRED TO REDUCE THE OUTPUT TO AN ACCEPTABLE LEVEL FOR THE DETECTOR.
POWER DETECTOR MOUNT
POWER METER
X-Y RECORDER
X
Y
(BLANKING RELAY OUTPUT)
PEN LIFT

FIGURE 3-12. GENERAL-PURPOSE TEST SET-UP FOR SWEPT OR SINGLE-FREQUENCY MEASUREMENTS

...no an oscilloscope or recorder Y-axis, or to a meter.

...2 DETAILED PROCEDURE. To make gain or loss meas-...s using the general set-up of Figure 3-12, a typical pro-...is as follows:

...r to Figure 3-12 and make rough calculations of neces-...pad attenuator values and/or the minimum setting of the ...ision attenuator to assure that permissible power levels ... not be exceeded, either at the equipment under test or ...e detector. Determine whether additional pre-detection ...ification will be required. Complete the test set-up, ...ng necessary modifications from the typical arrangement ...n in Figure 3-12 and setting the attenuator level(s).

...ust the Model 650 controls to establish the desired sweep ...leveling mode.

... the MODULATION Selector switch to AM EXT to turn ...he rf output while maintaining the OUTPUT SWEEP ...gal.

...ust the oscilloscope or recorder horizontal gain control ...btain the desired calibration in Gc per cm or Gc per ...

... the MODULATION Selector switch to AM OFF to ...ly rf output. Adjust the recorder or oscilloscope vertical ...rols as necessary to obtain a good presentation. Then ...rd a single performance trace on the recorder, or pre-...e the oscilloscope performance trace with a grease-...il mark. Note the precision attenuator setting at which ...trace is obtained. (If measurement of dynamic range is ...red, make additional trace measurements with different ...ings of the precision attenuator, and note both these ...nuator settings and the gain settings of the recorder or ...lloscope. If the latter must be changed, make changes only in the calibrated step amplification settings, not in the vernier.)

f. Remove the equipment under test from the test circuit, connecting the precision variable attenuator directly to the equipment output pad attenuator.

g. Without adjusting the oscilloscope or recorder controls, change the setting of the precision attenuator to produce a calibration trace which intersects the previously-recorded performance trace. Record several calibration traces, with different settings of the precision attenuator, to calibrate the performance trace at various points of intersection. The points of intersection of each calibration trace with the previously-recorded performance trace will calibrate that trace in db. The difference in db between the precision attenuator setting of each calibration trace, and that used for recording the performance trace, is the absolute db value of performance for each point of intersection. Interpolation can be used between calibration traces. [If several performance traces were made using different display gain settings, obtain additional calibration traces for those gain settings, or correct the existing calibration traces for those conditions, by taking into account the db value of the amplification change: The gain increment in db = 10 $\log_{10}$ (amplification decrease) when the crystal is in its square law range.]

h. Obtain recorder plots or oscilloscope photos for permanent record as desired.

i. Repeat Steps e. through h. for all devices to be tested.

3.17.6 TECHNIQUE FOR TRANSMISSION MEASUREMENTS WITH FLAT, PRE-CALIBRATED DISPLAY (See Figures 3-13 and 3-14).

3.17.6.1 GENERAL DATA. A technique similar to that

discussed in Paragraph 3.17.3 can be used for gain or loss measurement by comparing the incident and transmitted power levels. If the incident power is leveled at the load by use of an external sampling coupler located at the load, the incident power will remain constant over the test band. A single sampler or a detector connected directly to the device output, depending upon output level, can then be used to measure the transmitted power. In some test situations, it will not be possible to use a flat, tick-mark-calibrated readout display method outlined here, and the general procedure given in Paragraph 3.17.5 must be used. These situations include cases where high VSWR exists or where significant phase shift changes take place across the band with moderate VSWR; where the transmitted power detector must be operated above square-law level; where the output power cannot be leveled at the load or where a non-flat pad must be used to reduce the power level outside the leveled loop; and where non-flat couplers are used and the leveler sampler detector must operate above square-law range, thereby preventing automatic coupler compensation.

General test set-ups for loss measurements are shown in Figure 3-13, and a general set-up for gain measurement is shown in Figure 3-14. The basic test circuit is similar to that shown in Figure 3-11 for reflectometer measurements, except that the equipment under test is placed between the two couplers. Note that in the test set-ups shown in Figures 3-13 and 3-14, the operating power levels are kept within the square-law range of ALFRED Model 1001 Detectors. A pad attenuator can be used at the output of the Model 650 as necessary to reduce the level to the values shown. It is preferable to use maximally flat samplers or couplers, but the test circuits shown in Figures 3-13A and 3-14 will compensate for variations in coupler response across the band if matched couplers are used.

In Figure 3-13A, where the incident power sampling coupler and the output power sampling coupler are of identical value, the use of matched couplers with detectors in the square-law range will allow the couplers to compensate for each other. For greatest accuracy, the couplers used should have high directivity. In testing waveguide systems below 12.4 Gc, place a coax-to-waveguide adapter at the output of the Model 650 and at the input to the detectors, unless waveguide crystal detector mounts are used. This permits use of more accurate high-directivity waveguide directional couplers.

In set-ups where the detector is connected directly to the output of the equipment under test, or where different coupling values must be used to obtain workable power levels at the input and output, maximally-flat samplers or couplers must be used. Figure 3-14 shows how a maximally-flat coupler can be simulated for the leveler sampler loop by using two identical matched 3-db couplers in tandem. The detector arm of the first coupler is connected through the primary path of an identical matched coupler whose secondary terminal is terminated in a load. This technique does not apply to couplers of other values, however, unless they are specifically designed to provide matched compensation at different power levels.

Note that if an output coupler is used for gain tests it is not usually possible to use identical matched couplers for input and output power sampling because the power supplied to the leveler detector under such conditions would not provide sufficient output for leveling. Because of phase considerations in the leveling loop, it is not possible to add dc amplification between the leveler detector output and the RF SAMPLER INPUT jack. The maximum permissible gain in the leveling loop is that obtained when the RF SAMPLER SENS control is turned fully CCW. Thus, in gain tests where flat pads or flat couplers are not available, and in other test situations where matched couplers are not available, it may be preferable to use the general procedure with a precision variable attenuator for calibration of non-flat response, as given in Paragraph 3.17.5.

The procedures given below provide for loss and gain measurements which are calibrated to a direct-reading tick-mark scale located at any convenient point on the CRT graticule or recorder graph paper. Subject to the limitations discussed above, flat, leveled performance across the band eliminates the need for recording full-width calibration traces.

3.17.6.2 LOSS MEASUREMENT PROCEDURE. To calibrate the oscilloscope or recorder and carry out loss measurements, set up equipment as shown in Figure 3-13, and proceed as follows:

a. Adjust the Model 650 controls to establish the desired sweep mode and external leveling.

b. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

c. Adjust the oscilloscope or recorder horizontal gain control to obtain the desired calibration in Gc per cm or Gc per inch, from the Model 650 OUTPUT SWEEP drive signal.

d. Adjust the oscilloscope vertical offset controls to place the trace on the lowest horizontal line of the graticule (3 cm from center on a standard 6-cm scope). Adjust the recorder zero position as necessary to place the pen over the bottom line on the graph. This line corresponds to infinite attenuation (zero signal), which can be calibrated as ∞ on a direct reading scale of loss.

   NOTE: Detector output connections should be made to allow up-scale deflection on the oscilloscope or recorder.

e. In the circuit of Figure 3-13A, connect the input and output sampling couplers together at the point where the device under test would normally be inserted. In the circuit of Figure 3-13B, connect the output detector (and pad, if used) directly to the input sampling coupler, bypassing the device under test.

f. Turn the MODULATION Selector switch to AM ON and check for leveled output by observing that the UNLEVELED light is not lit. Adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the top line of the graticule or graph paper. Do not readjust the zero position controls. If the detected output level is above the square-law range of the detector used, reduce the Model 650 output power with the POWER LEVEL control.

   The line now being traced represents zero attenuation (full-strength signal). It can be calibrated as 0 db on a direct-reading attenuation scale on the CRT face or recorder chart paper.

g. The direct-reading attenuation scale may now be calibrated for the full range of attenuation from 0 db to ∞ by using a slide rule, a ruler or scale calibrated in divisions of the unit spacing on the CRT graticule or recorder graph paper, and the following equation:

   Definition of db ratios: (1)

$$\left(\frac{E_1}{E_2}\right)_{db} = 20 \log \frac{E_1}{E_2}$$

$$= 10 \log \frac{P_1}{P_2}$$

as measured with voltage signal from a square-law detector.

ample A

Calibrate the vertical center point of the 0 db to ∞ attenuation scale:

At the center point, the detector output signal is 1/2 that at the "0 db" point. Since the 0 db trace corresponds to the incident power level, the output signal which gives a center-scale deflection has 1/2 the power of the incident wave because square-law detector readings are directly proportional to power. From equation (1) above,

$$db = 10 \log \frac{2}{1} = 3 \text{ db}$$

Example B

Similarly, for a 6-unit scale such as a standard 6-cm CRT graticule, the divisional calibration points between 0 and ∞ can be calculated as 0.8 db, 1.8 db, 3.0 db, 4.8 db, and 7.8 db.

h. If the loss is more than 10 db, it will be convenient to increase the vertical amplification of the oscilloscope or recorder by a factor of 10 or more to increase the sensitivity of the direct-reading display. The db value of the amplification increase must be added to the loss read directly from the calibrated scale. If the output detector crystal is operating in its square-law range, the db value is 10 times the

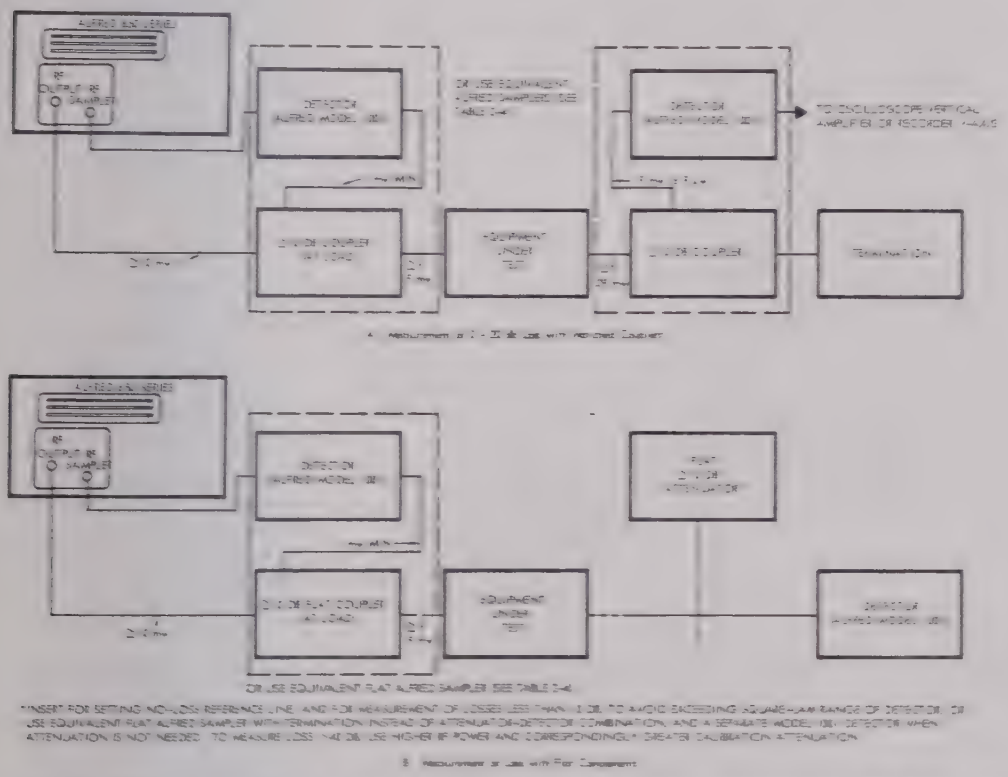


FIGURE 3-13. TRANSMISSION LOSS MEASUREMENTS USING CALIBRATED OSCILLOSCOPE OR RECORDER

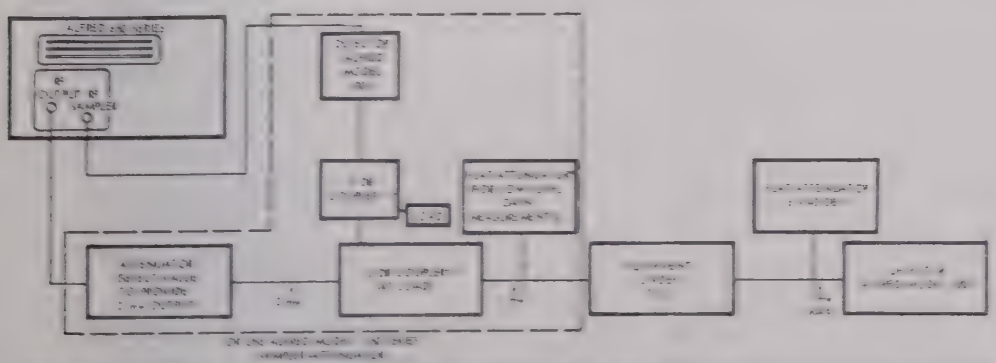


FIGURE 3-14. TRANSMISSION GAIN MEASUREMENTS USING CALIBRATED OSCILLOSCOPE OR RECORDER

$\log_{10}$ of the voltage amplification added: 10:1 = 10 db; 20:1 = 13 db; 50:1 = 17 db; 100:1 = 20 db. With these db values added, the scale can be read directly as previously calibrated.

Connect the device under test between the input and output couplers as shown in Figure 3-13. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, read the attenuation from the calibrated scale. If necessary, switch to another vertical channel amplification step that brings the trace closest to full-scale deflection. Then add the db value of the added amplififcation to the scale reading as directed in Step h.

i. Obtain recorder plots or oscilloscope photos for permanent record as desired.

j. Repeat Steps i. and j. for all devices to be tested.

3.17.6.3 GAIN MEASUREMENT PROCEDURE. To calibrate the oscilloscope or recorder and carry out gain measurements, set up equipment as shown in Figure 3-14, and proceed as follows:

a. Follow Steps a. through c. under Paragraph 3.17.6.2.

b. Follow Steps d. through f. under Paragraph 3.17.6.2, except in Step f. adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the CENTER line of the graticule or graph paper, not the top line. Also, do not mark calibrations on the scale; merely obtain reference points of 0 signal (bottom line) and full-strength signal (center line).

NOTE: To calibrate the set-up used for high gain measurements, it may be necessary to remove the attenuation from the output circuit when bypassing the device under test for calibration purposes, to restore the signal to a level commensurate with that to be measured during the test. Before making test measurements, re-insert the attenuation in the output circuit.

c. Use the zero offset controls to move the "full-strength signal" trace from the center line to the bottom line of the CRT graticule or graph paper. This becomes the 0 db gain reference.

d. Calculate scale values to calibrate the graph paper or graticule, based on the relation of each scale deflection point to the known half-scale deflection offset which represents the incident signal level. Use the equation given in Step g. of 3.17.6.2 above.

Example A

Calibrate the scale division points on a 6-cm scale:

Bottom Line: 0 db gain reference.

1st division: Power Level = 1 1/3 that of incident signal, since incident signal is calibrated for half-scale deflection before offset.
10 log 1.33 = 1.24 db.

2nd division: output = 1.66 x incident power
10 log 1.66 = 2.2 db.

3rd (center) division: 10 log 2 = 3 db

4th division: 10 log 2.33 = 3.67 db

5th division: 10 log 2.66 = 4.25 db

Top Line: 10 log 3 = 4.77 db

e. If the gain is more than 4.75 db, it will be necessary to decrease the vertical amplification of the oscilloscope sufficiently to bring the trace on-scale. In order to retain the scale calibration established above, this change of sensitivity must be made with only the stepped adjustment control, without changing the zero or calibration vernier adjustments previously set to calibrate the trace. The db value of any amplification decrease must be added to the gain read directly from the calibrated scale. If the output detector crystal is operating in its square-law range, the db value is 10 times the $\log_{10}$ of the amplification change ratio: 2:1 = 3 db; 5:1 = 7 db; 10:1 = 10 db; 20:1 = 13 db; 50:1 = 17 db; 100:1 = 20 db, etc.

NOTE: If the calibration was performed with the output detector connected directly to the primary output terminal of the input coupler, the db value of the output attenuator or coupler which was bypassed for calibration must be added to the gain read directly from the calibrated scale during performance measurements. If in this case the vertical amplification must be increased to obtain an on-scale test measurement presentation, the db value of this increase must be subtracted from the gain reading. Hence, the scale in this case is augmented by an amount equal to the output attenuator loss or coupler ratio, less any increase in vertical amplification in db.

f. Connect the device under test into the test circuit as shown in Figure 3-14. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, read the attenuation from the calibrated scale. If necessary switch to another vertical channel amplification step that brings the trace closest to full-scale deflection. Then interpret the db value of the scale reading as directed in Step e.

g. Obtain recorder plots or oscilloscope photos for permanent record as desired.

h. Repeat Steps f. and g. for all devices to be tested.

3.17.7 TECHNIQUE FOR VSWR MEASUREMENTS WITH DIRECT-READING METERS. A direct-reading VSWR meter may be connected to the reflected power detector output shown in Figure 3-11, replacing an oscilloscope or recorder. The proper location for connection of a direct-reading VSWR meter is also shown in Figure 3-12. A direct-reading ratio meter may be driven by using internal leveling in the Model 650 and utilizing the incident power sampling coupler shown in Figures 3-11 and 3-12 to drive the reference channel of the ratio meter. Measurement techniques using these specialized meters are covered adequately in the instruction manuals for such meters. They may be used with either single-frequency operation or slow (100-second sweep) swept-frequency operation.

3.17.8 TECHNIQUE FOR POWER MEASUREMENT WITH DIRECT-READING METERS. A direct-reading power meter may be used by terminating the output circuit from the device under test at its power detector mount. The connection must be made through a suitable attenuator pad (or a coupler) to reduce the incident power level to that acceptable to the detector mount, which is usually 10 mw maximum. Measurement techniques are covered adequately in the instruction manuals for these meters. For greatest accuracy, single-frequency operation should be used. With some power meters, slow (100-second sweep) swept-frequency operation may be used.

-1, Sheet 1

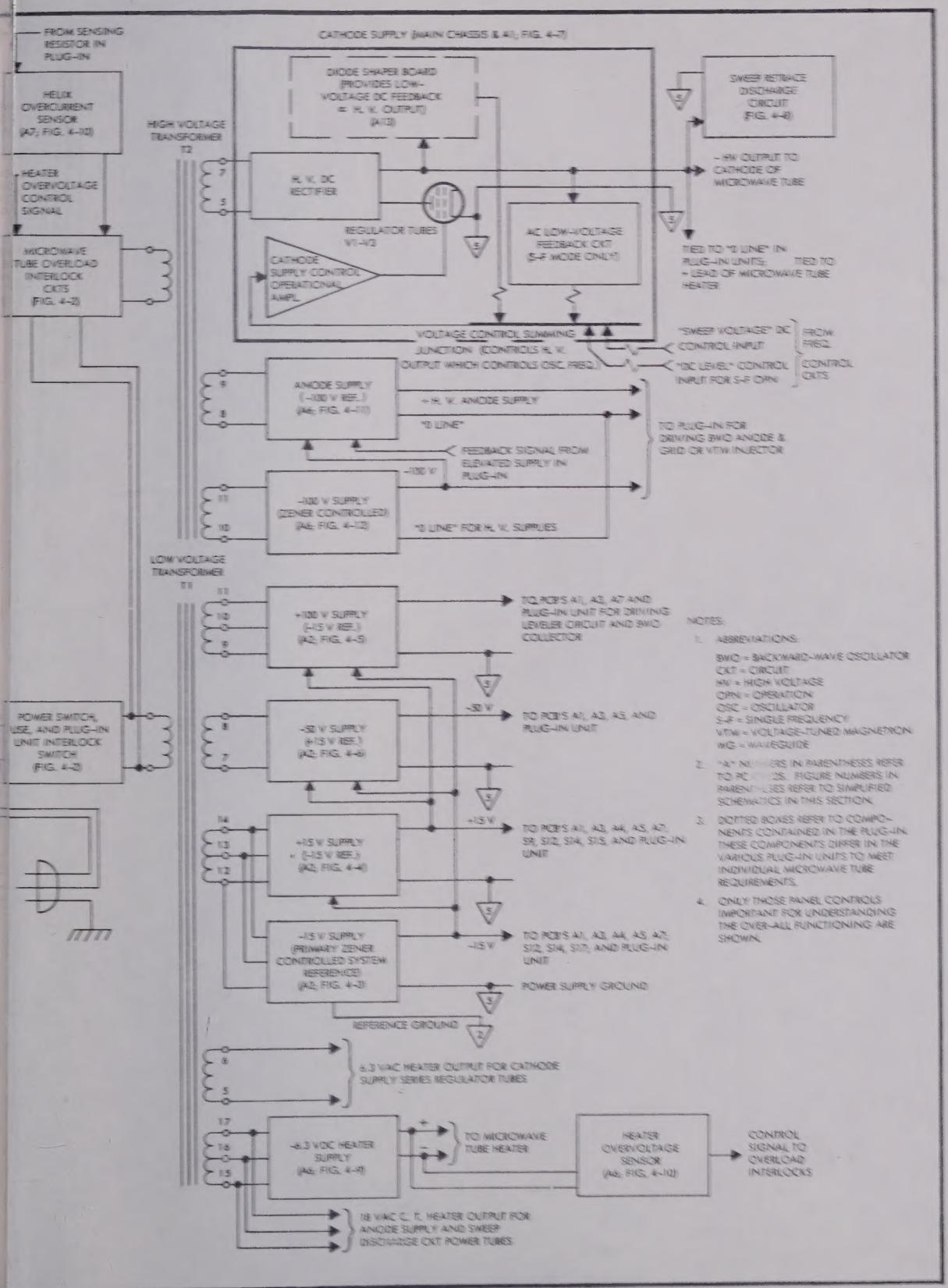

FROM SENSING RESISTOR IN PLUG-IN
HELIX OVERCURRENT SENSOR (A7; FIG. 4-10)
HEATER OVERVOLTAGE CONTROL SIGNAL
MICROWAVE TUBE OVERLOAD INTERLOCK CKTS (FIG. 4-2)
HIGH VOLTAGE TRANSFORMER T2
CATHODE SUPPLY (MAIN CHASSIS & A1; FIG. 4-7)
DIODE SHAPER BOARD (PROVIDES LOW-VOLTAGE DC FEEDBACK ∝ H. V. OUTPUT) (A1T3)
H. V. DC RECTIFIER
REGULATOR TUBES V1-V3
CATHODE SUPPLY CONTROL OPERATIONAL AMPL.
AC LOW-VOLTAGE FEEDBACK CKT (S-F MODE ONLY)
SWEEP RETRACE DISCHARGE CIRCUIT (FIG. 4-8)
-HV OUTPUT TO CATHODE OF MICROWAVE TUBE
TIED TO "0 LINE" IN PLUG-IN UNITS; TIED TO -LEAD OF MICROWAVE TUBE HEATER
VOLTAGE CONTROL SUMMING JUNCTION (CONTROLS H. V. OUTPUT WHICH CONTROLS OSC. FREQ.)
"SWEEP VOLTAGE" DC CONTROL INPUT
FROM FREQ. CONTROL CKTS
"DC LEVEL" CONTROL INPUT FOR S-F OPN
ANODE SUPPLY (-100 V REF.) (A6; FIG. 4-11)
+H. V. ANODE SUPPLY
"0 LINE"
TO PLUG-IN FOR DRIVING BWO ANODE & GRID OR VTW INJECTOR
FEEDBACK SIGNAL FROM ELEVATED SUPPLY IN PLUG-IN
-100 V
-100 V SUPPLY (ZENER CONTROLLED) (A6; FIG. 4-12)
"0 LINE" FOR H. V. SUPPLIES
LOW VOLTAGE TRANSFORMER T1
+100 V SUPPLY (-15 V REF.) (A2; FIG. 4-5)
TO PCB'S A1, A3, A7 AND PLUG-IN UNIT FOR DRIVING LEVELER CIRCUIT AND BWO COLLECTOR
-50 V SUPPLY (+15 V REF.) (A2; FIG. 4-6)
-50 V
TO PCB'S A1, A3, A5, AND PLUG-IN UNIT
+15 V SUPPLY (-15 V REF.) (A2; FIG. 4-4)
+15 V
TO PCB'S A1, A3, A4, A5, A7; S9, S12, S14, S15, AND PLUG-IN UNIT
-15 V SUPPLY (PRIMARY ZENER CONTROLLED SYSTEM REFERENCE) (A2; FIG. 4-3)
-15 V
TO PCB'S A1, A3, A4, A5, A7; S12, S14, S17; AND PLUG-IN UNIT
POWER SUPPLY GROUND
REFERENCE GROUND
6.3 VAC HEATER OUTPUT FOR CATHODE SUPPLY SERIES REGULATOR TUBES
-6.3 VDC HEATER SUPPLY (A6; FIG. 4-9)
TO MICROWAVE TUBE HEATER
HEATER OVERVOLTAGE SENSOR (A6; FIG. 4-10)
CONTROL SIGNAL TO OVERLOAD INTERLOCKS
18 VAC C. T. HEATER OUTPUT FOR ANODE SUPPLY AND SWEEP DISCHARGE CKT POWER TUBES
POWER SWITCH, FUSE, AND PLUG-IN UNIT INTERLOCK SWITCH (FIG. 4-2)
NOTES:
1. ABBREVIATIONS:
BWO = BACKWARD-WAVE OSCILLATOR
CKT = CIRCUIT
HV = HIGH VOLTAGE
OPN = OPERATION
OSC = OSCILLATOR
S-F = SINGLE FREQUENCY
VTW = VOLTAGE-TUNED MAGNETRON
WG = WAVEGUIDE
2. "A" NUMBERS IN PARENTHESES REFER TO PC ASSEMBLIES. FIGURE NUMBERS IN PARENTHESES REFER TO SIMPLIFIED SCHEMATICS IN THIS SECTION.
3. DOTTED BOXES REFER TO COMPONENTS CONTAINED IN THE PLUG-IN. THESE COMPONENTS DIFFER IN THE VARIOUS PLUG-IN UNITS TO MEET INDIVIDUAL MICROWAVE TUBE REQUIREMENTS.
4. ONLY THOSE PANEL CONTROLS IMPORTANT FOR UNDERSTANDING THE OVER-ALL FUNCTIONING ARE SHOWN.

FIGURE 4-1. BLOCK DIAGRAM OF MODEL 650 SERIES (SHEET 1: POWER SUPPLY CIRCUITS)

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